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ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL SCIENCE
SCHOOL OF INFORMATION SCIENCE

KNOWLEDGE BASED SYSTEM FOR MATERNITY CARE,
TREATMENT AND PREVENTION

BISILE KEBEDE

January, 2017

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A Thesis is Submitted to the school of information science Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Science.

BY
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January, 2017

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LIST OF ACRONYMS

AI -----Artificial Intelligence

KBS -----Knowledge-based system

KBSMCT --- knowledge based system for maternity care and treatment

KE ----- Knowledge Engineer

KE ----- Knowledge elicitation

KA ----- Knowledge acquisition

WHO -----World Health Organization

RBR-----Rule Based Reasoning

CBR -----Case Based Reasoning

KB -----Knowledge Based

KR -----Knowledge Representation

ABSTRACT

In developing countries like Ethiopia, fulfilling every aspect of health issues is an immense challenge. These challenges are confronted in different sectors by various methods. The stakeholders include governments, non-governmental organizations and private sectors. Among the efforts of United Nations organization to fulfill this goal includes, setting international plans such Millennium development Goal, Supporting countries in financial, human resource, training and infrastructure. Despite of all these efforts, maternal mortality ratio in sub-Saharan Africa is still in its highest rate in the world. In Ethiopia, MMR (Maternal Mortality Ratio) in 2013 is 420 deaths per 100,000 live births. United Nations set to reduce this number to 350 deaths per 100,000 live births in 2015. Major challenge for health service in Ethiopia is shortage of skilled manpower in the health sector. Quality of Maternity care is compromised due to services provided by less skilled personnel. As part of the stakeholders in this regard, information technologies play a significant role. The objective of this system is to develop a knowledge base system that assists Health workers in decision making process related to maternal cases. The limitations of human power are overcome by the diligence of computer systems like this. This system can be used by low level to high skilled health professionals. Hence, consistency among maternity care decisions is achieved. The quality of service to maternal women is also improved. To achieve the expectations of this system, the methodologies followed in this system are knowledge acquisition using Interview is used as one of primary knowledge source which we can gather the needed knowledge from knowledge experts such as Doctors, Gynecologists, and Midwifery Nurses face-to-face. Domain experts were selected by using purposive sampling techniques. Semi-structured interviews can be used to gather qualitative information. For the research will use decision tree modeling in formal language which is suitable for rule based system. From decision tree the prototype is developed using SWI-prolog, which uses rule based ('if - then') rules. After the development of knowledge based system verification and validation tests are conducted. The verification test of knowledge based system is tested in two categories, code standard by ICT staff and user acceptance by domain experts. According to ICT staffs 80% of the code is up to the standard and 82% of the users are satisfied with system.

In addition, the performance of the system is evaluated by using validation techniques with twenty test cases, which five cases are assigned for each maternal visit. The results of the validation test case indicate that 90% of cases are similarly treated.

The main challenges faced during the studies are medical knowledge is difficult to understand with in short time, the schedule of the experts are crowded and others are discussed. Finally, some recommendations are forwarded.

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Knowledge based system is a software that uses artificial intelligence or expert system techniques in problem solving processes. It incorporates a store of expert knowledge with couplings and linkages designed to facilitate its retrieval in response to specific queries, or to transfer expertise from one domain of knowledge to another (Darai, 2010)

The term artificial intelligence was first coined by John McCarthy in 1956 when he held the first academic conference on the subject. But the journey to understand if machines can truly think began much before that. According to smith (2006), Vannevar Bush in his seminar work named “*As We May Think*” proposed a system which amplifies peoples’ own knowledge and understanding. Five years later Alan Turing wrote a paper on the notion of machines being able to simulate human beings and the ability to do intelligent things, such as play Chess (Smith, 2006).

The AI systems effectively distribute the scarce resources for the development process. The Knowledge-Based Systems (KBS), which are a step towards an intelligent system, can be justified when a few individuals have the majority of the knowledge (Srinivas, 2010). Any development system requires a sequence of engineering and management decisions which must satisfy many competing requirements. Acquiring and formulating the related knowledge. This step included collecting relevant pieces of knowledge and information from experts. Knowledge is represented in the form of rules or other representation techniques and stored in a knowledge base. Testing the knowledge base for validation can be done comparing performance of human experts with system (Calkins, 2000).

Development of an intelligent system by itself is a challenge in terms of knowledge acquisition, knowledge representation and knowledge inference because there are differences between one individual to other.

Expert may be able to communicate the knowledge needed to knowledge engineer. Knowledge engineer may not be able to structure knowledge for entries into knowledge base are some of challenge during knowledge acquisition process.

The size of knowledge base we are dealing with is also one challenge in managing knowledge base since representing that knowledge in a computer readable format is also a challenge. The need of constantly updating knowledge base system because of frequent changes in the real world is also a challenge in the area (Sharma, 2010).

1.2. Overview of Maternity Care

Maternity health is a critical issue in the whole world. Millions of Ethiopians, especially those who live in rural areas, are exposed to a variety of preventable diseases. Maternal, infant and under-five mortality rates are still among the highest in the world.

Millennium Development Goal 5 (MDG 5) aims to improve maternal health, with a target of reducing the Maternal Mortality Ratio (MMR) by 75% between 1990 and 2015 and a second one on achieving universal access, by 2015, to reproductive health (Calkins, 2000). For Ethiopia, WHO modeled data for 2013 revealed a maternal mortality rate (MMR) of 420/100,000 Live Births with a goal of 350 in 2015 (WHO, 2014). However, according to the EDHS 2011, the country continues to experience one of the highest maternal mortality ratios in Africa at 676 per 100, 000 live births. Maternal deaths can be classified into two based on their causes that is either direct or indirect maternal deaths. Direct maternal deaths are those resulting from obstetric complications of the pregnant state (i.e. pregnancy, delivery and postpartum), interventions, omissions, incorrect treatment, or a chain of events resulting from any of the above. For example, death due to obstetric hemorrhage or hypertensive disorders in pregnancy, or those due to complications of anesthesia or caesarean section are classified as direct maternal deaths. Indirect maternal deaths are those resulting from previously existing diseases, or from diseases that developed during pregnancy and that were not due to direct obstetric causes but aggravated

by physiological effects of pregnancy. For example, deaths due to aggravation of an existing cardiac or renal disease are considered indirect maternal deaths (WHO, 2014). In Ethiopia direct obstetric complication accounts for 85% of the deaths. It includes abortion 32%, obstructed labor 22%, sepsis 12%, and hemorrhage 10% and hypertension 9%, primarily due to frequency of adolescent pregnancy combined with neglected prolonged labor.

Most of these deaths are preventable when access to adequate reproductive health services, equipment, supplies and skilled healthcare workers.

Some of the factors contributing to these problems are the number of health facilities, number of health professionals, number of intensive care unit, number of blood bank and availability of the selected essential drug (Muhammedawel, 2014; Yifru, 2014).

1.3. Statement of the Problem

The World Health Organization (WHO, 2014) estimates that 580,000 women of reproductive age die each year from **complications** arising from pregnancy, and a high proportion of these **deaths** occur in sub-Saharan Africa.

The ratio of maternal mortality in the region is one of the highest in the world, reaching levels of 686 per 100,000 live births (Yared, 2002). In Ethiopia, the ratio of physicians per people is 0.1 to 0.3 and that of hospital to people is 0.1 to 0.2 (Yifru, 2014). The facilities needed to keep mothers from dying of maternal complications need more capital and very skilled human power which is not adequately and widely affordable before our country get in the order of developed countries. However, our mothers should not continue dying until we get developed.

The report between 1990 and 2013 regarding maternity health acknowledge the increase in **Antenatal visits** and **births attended by skilled health personnel** had great contribution. Half of pregnant women in the developing regions receive the recommended minimum of four antenatal care visits. Lack of adequate antenatal visits is related poor delivery outcome, resulting in need for skilled health personnel attendant and this is not sufficiently available. This study is motivated by the fact derived from the United Nation's report of 23 years maternal mortality progress. The report clearly indicated that skilled health professionals' involvement in maternal

health play the major role. This study helps to create the environment for skilled health professionals through knowledge base system support to decision makers.

Despite the availability of limited maternal health and related professionals, facility directed at such a group of professionals and some decisions may differ considerably depending on their professional skills, their experience, local diagnostic equipment etc. The problem of any early pregnancy disorder (EPD) must always be seen as an emergency as its prompt detection may prevent complications including those that are life-threatening. To identify and decide upon this case needs properly organized knowledge and skill during the consultation as well as diagnosis time (Ruszkowski, 1988). The habit of updating old medical knowledge which is not well matured in case of medical professionals is a barrier to maternal health care development.

So far, there are many researches made in Knowledge Based System. But few are related to General Health and KBS. Even very few are made specifically concerning maternal health.

Ruszkowski (1988) noted, expert knowledge based consultation for Early Pregnancy Disorders, has used expert knowledge acquisition and rule based methods. The objectives proposed in his work are: suitable consultation procedures concerning EPD (Early Pregnancy Disorder) and comprehensive and reliable medical knowledge acquisition. Ruszkowski (1988) has not mentioned anything to predict whether this Early Disorders give rise to “Death” or “Not Death” which helps to take every possible caution in the course of delivery.

Tagel (2013), who was a Post graduate candidate in 2013 in Addis Ababa University, School of Information Science, researched on Knowledge based system for Pre-medical triage treatment. The main challenge Tagel try to address is about the shortage of skilled health professionals compared to highly spreading chronic diseases in sub Saharan Africa, specifically Ethiopia. The main focus of the research is pre-medical triage (sorting and allocation of treatment to patients) for chronic diseases.

This research starts by checking mother week of pregnancy and mother follow-up.

The aim of this study is to design a knowledge based system that provide advice for decision making during the consultation time in early pregnancy follow up as well as the diagnosis

process and as a problem happens. This contributes to eliminating knowledge differences among health professionals.

The research questions of this study are the following:

- What are the knowledge used by human experts in the course of maternity care and treatment?
- What are the suitable models, representation techniques and implementing tools that are applicable to the proposed knowledge based system?
- To what extent performance and user satisfaction is obtained with the proposed knowledge based system?

1.4. Objectives of the study

1.4.1. General Objective

The general objective of this study is to develop a knowledge base system that assists Health workers in providing timely treatment to pregnant mothers so as to minimizing maternity mortality.

1.4.2. Specific Objectives

To achieve the general objective the following specific objectives are identified:

- To collect, organize and analyze data concerning maternity from literature and knowledge experts.
- To select suitable KBS technologies for Knowledge acquisition, Knowledge Modeling, Knowledge representation and Knowledge base.
- To develop prototype knowledge based system for maternity treatment service.
- To test and validate the performance of the knowledge based system.

1.5. Scope and limitation of study

This study was conducted to determine the use of knowledge based system in maternity care and follow up towards filling the knowledge gap of health professional of the sector. There are many techniques for the development of knowledge base system. For the purpose of this research rule based approach is used. The rules the study use are limited to diagnose pregnant mother and provide possible suggestion to make appropriate decisions by human experts and to further examine the mother's case and new born child.

The focus of this study is limited to health professionals involved in the care and follow-up of pregnant women. The data collection for the knowledge acquisition was also conducted from these groups.

More attention is given in this study to the following areas:

- For the pregnant mother the system suggest follow-up and diagnose as the problem happen or it works on ANC.
- The system also works on the postnatal care for mothers and
- types of delivery to be taken in some conditions.

Some of the major constraints during the knowledge based system development are:

- Medical knowledge is difficult to understand with in short time and this caused knowledge acquisition process difficult.
- Experts are busy to take time to support the research.
- Some of the health professionals are not familiar with proposed system and it takes a lot of time to introduce the objective of the study.
- Some of the professionals are not confident and able to articulate domain knowledge.
- Representing and codifying natural language into computer language is the challenging and time consuming task.

1.6. Research Methodology

Research methodologies implemented in order to make sure the goal of this research is implemented successfully. For this study empirical study is used that combine experimental and non-experimental research. As research process model knowledge engineering is followed in the process of knowledge based system development.

Knowledge engineering (KE) was defined in 1983 by Edward Feigenbaum and Pamela McCorduck (Darai, 2010). KE is an engineering discipline that involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human expertise (Darai, 2010). Knowledge Engineering steps to follow in order to accomplish successful knowledge based system are discussed below.

1.6.1. Knowledge Acquisition

For the purpose of this study, both primary and secondary data collection methods are employed to collect the required domain knowledge. The knowledge acquisition process incorporates typical fact finding methods like interviews, questionnaires, record reviews and observation to acquire factual and explicit knowledge and concept sorting, concept mapping, and protocol to extract tacit knowledge (Potter, 20014). Out of these techniques for this research the followings are selected. Interview is one of the primary method for acquiring knowledge from source, which we can gather the needed knowledge from knowledge experts such as Doctors, Gynecologists, and Midwifery Nurses face-to-face. One of the advantage of using Interviews are it can be taped and later transcribed and analyzed. Semi-structured interviews can be used to gather qualitative information. Interviews of this type are suited to working with small samples and are useful for studying specific situations or for supplementing and validating information derived from other sources used for making safety diagnoses.

In addition, since they provide access to perceptions and opinions, they are effective for gaining insight into problems that are not immediately perceptible (Laforest, 2009). For the purpose of this study the researcher takes the advantages of semi-structured interviews. Domain experts were selected by using purposive sampling techniques.

Purposive sampling is a probabilistic technique that does not need underlying theories or a set number of informants. In other words the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience (Tongco, 2007).

Observation is also another method used for acquiring knowledge from source. We observe how maternity cases are handled in Health institutions such as Hospitals and other Health institutions. Using observation helps knowledge engineer to have new insight during the observation.

Document review is method for acquiring knowledge from secondary source.

1.6.2. Knowledge Modeling and Representation

Knowledge model views knowledge acquisition as the construction model of problem-solving behavior, that is, a model in terms of knowledge instead of representations. In this research decision tree modeling is used in formal language which is suitable for rule based system.

There are various knowledge representation schemes in AI. All knowledge representation (KR) techniques have their own semantics, structure as well as different control mechanism and power. For this thesis the Rule based representation techniques will be used. Rule representation is especially applicable when there is a need to recommend a course of action based on observable events. Rules are known as IF-THEN rules

Using rule base the system will perform diagnosis from the early beginning of mother pregnant to end of the cycle (till ninth month), and how maternity care is handled before, during and after delivery. Generally, using rule based reasoning the system diagnoses pregnant woman depending on her follow up history (Okafor, 2007).

1.6.3. Design and Implementation

To design and implement the proposed study of knowledge based system the researcher used prolog (logical programming) language. Prolog is one of the most popular logical programming languages in the discipline of artificial intelligence (AI). Prolog makes the representation of the solution much easier, allowing one to concentrate on solving the problems rather than coding the

solution (Tagel, 2013). As it is discussed before the research uses rule based knowledge representation and prolog is used for the implementation of rule based system.

1.6.4. Testing and Evaluation

The developed knowledge based system is tested based on the acceptance of user, whether the need of users is addressed or not. The system is tested using different mechanism. Validation provides evidence upon which users decide whether or not a knowledge-based system (KBS) is reliable. Validation in due course determines the success or failure of a KBS. This can be tested by using test cases, confusion matrix or other techniques. To test system five test cases are selected for each four visits and compared with how the systems perform in respect to expert. *Verification* is the process of checking an ES /KBS against the specifications generated by its requirements. The verification process produces accurate responses about the satisfaction of each specification. Questioner is used to check if user requirement is satisfied or to what extent satisfied. ICT staffs tested code standard of the system and experts tested over whole system acceptance for their use.

1.7. Significance of the Study

In Ethiopia, the physician to population ratios in the 1990 and 2010 were 0.3:10,000 people or 1:30,000 and 0.2:10,000 or 1:53,000, respectively. The magnitude of the problem becomes more severe when the population size is compared with the number of gynecologists (Yifru, 2014).

In the first half of 2013, at the national level regardless of working place, there were about 200 gynecologists, making the gynecologist to population ratio about 1: 450,000 (Yifru, 2014). The proposed research contributes in solving these problems and others in the following way:

- The proposed research contributes in reducing the number maternity mortality rate, by providing knowledge from stored knowledge base.
- The result of the study also minimizes the differences among medical decisions of Health professionals.
- The result of the study reduces burden of the health workers.

- The research will also contribute to minimize the cost of Health facilities used as an input to decision making, by assisting most of the input to be from the knowledge base.
- The study also helps health institutions to enhance their competency, because the proposed study minimizes limitation of man power.

1.8. Organization of the thesis

The thesis is organized into six chapters. Chapter one includes background of the study, overview of maternity care, statement of problem, objectives, scope and limitations of the study, research methodology and the significance of the study. Chapter two is literature review on knowledge based system architecture, knowledge engineering processes, and knowledge based system in medical domain. Chapter three discusses the knowledge acquisition, representation and conceptual modeling procedures; Chapter four deals with implementation of knowledge based system. Chapter five discussed testing of the system.

Finally, chapter six focuses on the conclusion and recommendation based on the results of the research finding for further research work in the domain area.

CHAPTER TWO

Literature Review

Artificial intelligence (AI) is a field of computer science that explores computational models of problem solving, where the problems to be solved are of the complexity of problems solved by human beings (McDermott, 2007). The term artificial intelligence was first coined by John McCarthy in 1956 when he held the first academic conference on the subject. John McCarthy, one of the organizers of the Dartmouth workshop and later moved to MIT. But the journey to understand if machines can truly think began much before that. According to Smith, Vannevar Bush in his seminar work named “As We May Think” proposed a system which amplifies people’s own knowledge and understanding. Five years later Alan Turing wrote a paper on the notion of machines being able to simulate human beings and the ability to do intelligent things, such as play Chess (Smith, 2006). John McCarthy also defined the high-level language which is called LISP, the later dominant programming language in AI and expert systems. In 1958, McCarthy presented a paper, ‘Programs with Common Sense’, in which he proposed a program called the Advice Taker to search for solutions to general problems of the world. Marvin Minsky also moved to MIT and has major contribution to knowledge engineering. In summary, we can say that in the 1960s, AI researchers attempted to simulate the complex thinking process by inventing general methods for solving broad classes of problems. They used the general-purpose search mechanism to find a solution to the problem (Negnevitsky, 2005).

2.1. Knowledge Based System

Expert system is one of the major parts of artificial intelligence. An expert system and knowledge based system can be used interchangeably and it is defined as, a computer program that contains the knowledge and analytical skills of one or more human experts in a specific problem domain. The goal of the design of the expert system is to capture the knowledge of a human expert relative to some specific domain and code this in a computer in such a way that the knowledge of the expert is available to a less experienced user. Knowledge based system is a computer program that simulates the judgment and behavior of a human that has expert knowledge and experience in a particular field. It contains a knowledge base containing accumulated experience and a set of rules.

Knowledge based system provides high quality experience, domain specific knowledge; apply heuristics, forward or backward reasoning, uncertainty and explanation capability. Knowledge based systems are designed to emulate an expert in a specialized knowledge domain such as medicine or any other area of knowledge where there is a shortage of expert knowledge (Tripathi, 2011).

2.2. Knowledge-Based System Architecture

The KBS consists of a Knowledge Base and a search program called Inference Engine (IE). The IE is a software program, which infers the knowledge available in the knowledge base. Inference Engine is a brain of expert system. It uses the control structure and provides methodology for reasoning. It acts as an interpreter which analyzes and processes the rules. It is used to perform the task of matching antecedents from the responses given by the users and firing rules. The major task of inference engine is to trace its way through a forest of rules to arrive at a conclusion.

The knowledge base contains the knowledge necessary for understanding, formulating and for solving problems. It is a repository of the domain specific knowledge captured from the human expert via the knowledge acquisition module. The knowledge base can be used as a repository of knowledge in various forms. As an expert's power lies in his explanation and reasoning capabilities, the expert system's credibility also depends on the Explanation and Reasoning of the decision made/suggested by the system.

Explanation is a subsystem that explains the system's actions. The explanation can range from how the final or intermediate solutions were arrived at to justifying the need for additional data. Also, human beings have an ability to learn new things and forget the unused knowledge from their minds. Here user would like to ask the basic questions why and how and serves as a tutor in system's knowledge with the user. Simulation of such learning is essential component of KBS. The life of KBS may vary according to the degree of such simulation. KBS may be either manually updated or automatically updated by machine. Ideally, the basic frame of a KBS rarely needs to be modified. In addition to all these, there should be an appropriate User Interface, which may have the Natural Language Processing facility. Figure 1 below shows knowledge based system architecture.

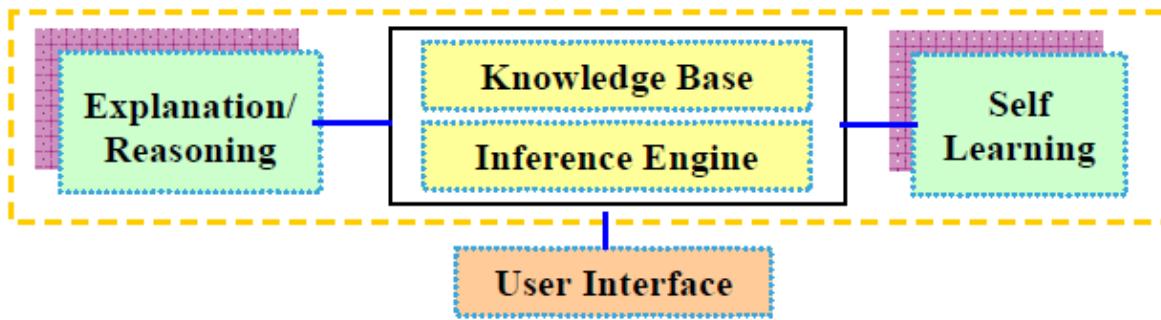


Figure 1 Architecture of a Knowledge-Based System (Srinivas, 2010).

2.3. The Knowledge engineering process

As presented in figure 2 below, the main components in the development of knowledge based system includes: Knowledge acquisition, knowledge validation and verification, knowledge representation, which discussed below.

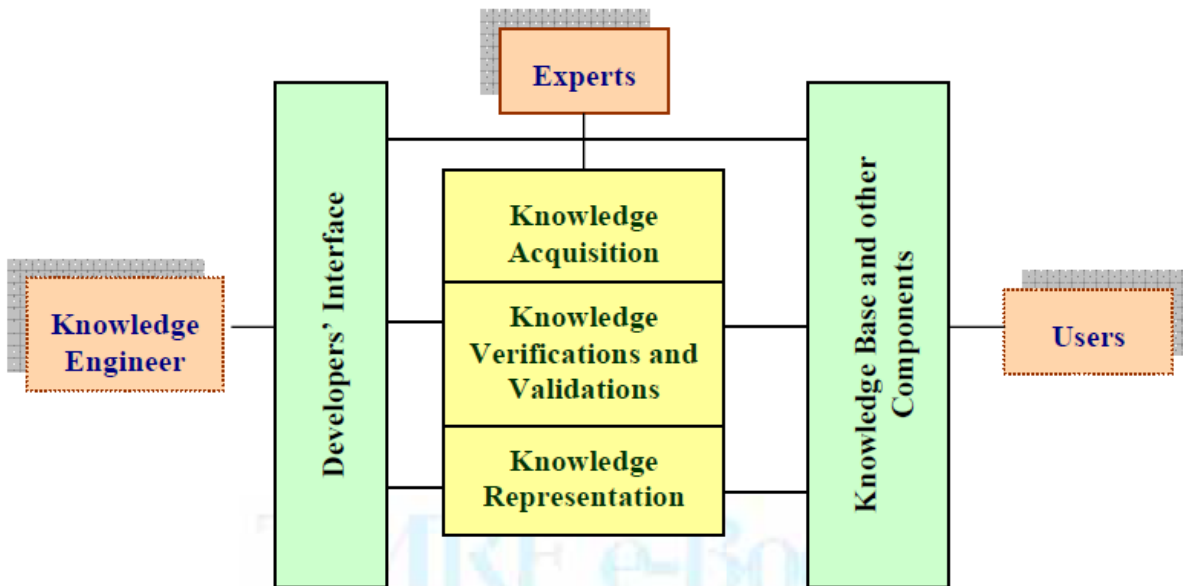


Figure 2 Knowledge base system development processes (Srinivas, 2010).

2.3.1. Knowledge Acquisition

Knowledge acquisition is the process of eliciting, structuring and organizing elicited knowledge from domain experts and other sources for knowledge base representation in form of rules or other forms of representation.

It is imperative to the development and implementation of expert systems for it contains the information required to solve problems in expert system domain.

As a result of the challenges and difficulties faced in the transfer of expertise knowledge, knowledge acquisition has been described as the bottle neck of expert systems development. The first challenge of knowledge acquisition, the logic or justification behind an expert's thought is not easily revealed and the omission of this tacit knowledge could cause a detrimental gap in knowledge required by an expert system to solve the problem for which it was built. Another major challenge in knowledge acquisition is experts' lack of willingness to share knowledge. In an academic and research environment, an expert is part of an expert system development team and he/she is acknowledged in the resulting research paper or article. However, expert systems development within a company /organization with the explicit intention of completely or partially replacing the domain expert hinders the co-operation and enthusiasm of domain experts as the threat of losing their jobs or prestige becomes perceptible.

Explicit knowledge is knowledge that the knower can make explicit by means of verbal statement: some has explicit knowledge of something if a statement of it can be elicited from him by suitable enquiry. Explicit knowledge can be expressed and communicated linguistically

2.3.1.1. Interviews

An interview between a human expert and a knowledge engineer is probably the most common form of knowledge acquisition. Interviews are usually taped and later transcribed and analyzed. Interviews are a widely used tool to access people's experiences and their inner perceptions, attitudes, and feelings of reality. Based on the degree of structuring, interviews can be divided into three categories: structured interviews, semi-structured interviews, and unstructured interviews (Zhang, 2009).

Structured interview

A structured interview is an interview that has a set of predefined questions and the questions would be asked in the same order for all respondents. This standardization is intended to minimize the effects of the instrument and the interviewer on the research results. Structured interviews are similar to surveys, except that they are administered orally rather than in writing (Zhang, 2009).

Semi-structured interview

Semi-structured interviews are more flexible. An interview guide, usually including both closed-ended and open-ended questions, is prepared; but in the course of the interview, the interviewer has a certain amount of room to adjust the sequence of the questions to be asked and to add questions based on the context of the participants' responses (Zhang, 2009).

Unstructured interview

This type of interview is non-directed and is a flexible method. There is no need to follow a detailed interview guide. Each interview is different. Interviewees are encouraged to speak openly, frankly and give as much detail as possible. The interviewers ask questions that respondents would be able to express their opinions, knowledge and share their experience. This can create some problems because the interviewer may not know what to look for or what direction to take the interview. The researcher may not obtain data that is relevant to the question of the study. The interviewer needs to think about what to ask and to ask questions carefully and phrase them properly and know when to probe and prompt (Kajornboon, 2005).

2.3.1.2. Observation

Sometimes it is possible to observe an expert at work. In many ways, this is the most obvious and straightforward approach to knowledge acquisition. However, there are different difficulties that should be considered. For example, most experts advise several people and may work in several domains simultaneously. In this case, the knowledge engineer's observations will cover all the other activities as well. Therefore, large quantities of knowledge are being collected, of

which only a little is useful. Observations are used primarily as a way of supporting verbal protocols. They are generally expensive and time-consuming.

2.3.1.3. Document analysis

The final form of knowledge acquisition method is concerned with a detailed analysis of the existing document. This technique is used to collect relevant knowledge from the existed documents of different format. These documents include professional literature, brochures, manuals, guidelines, employee handbooks, reports, glossaries, course texts, and other relevant materials (Tagel, 2013). For the purpose this study document analysis is chosen because the document prepared by minister of health is their main guidance for maternity related cases (Ministry of Health, 2010).

2.3.2. Knowledge Representation

Knowledge representation is important in the expert systems development as it affects the development, efficiency, speed and maintenance of an expert system. The knowledge acquisition process should fit in with knowledge representation paradigm and the knowledge representation should also be adequate for the problem. Knowledge representation can be described in contexts of both the inference and problem solving strategies of a proposed expert system.

2.3.3. Knowledge Verification and Validation

Validation provides evidence upon which users decide whether or not a knowledge-based system (KBS) is reliable. Validation in due course determines the success or failure of a KBS. This can be tested by using test cases, confusion matrix or other techniques and user acceptance (Preece, 2001).

2.3.4. Explanation Facility

Explanation facility is a subsystem that explains the system's actions. The explanation can range from how the final or intermediate solutions were arrived at to justifying the need for additional data.

2.4. Knowledge based system reasoning techniques

There are different reasoning techniques, including rule-based reasoning, case-based reasoning, etc.

2.4.1. Rule based reasoning

A Rule based reasoning system has an inference engine that uses rules to reach conclusions based on premises and a certain context state (Mariana, 2010). Rule based reasoning technique represents how a system solves a problem by using knowledge of the application domain that is represented in form of rules. Rules are one of the most popular knowledge representation and reasoning methods. Their popularity is because of their naturalness, which is suitable for comprehension of the represented knowledge. The basic form of a rule is, if <conditions> then <conclusion> where <conditions> represents the conditions of a rule, whereas <conclusion> represents its conclusion. The conditions of a rule are connected between each other with logical connectives such as, AND, OR, NOT, etc., thus forming a logical function. When sufficient conditions of a rule are satisfied, the conclusion is derived and the rule is said to trigger. Rules represent general knowledge regarding a domain (Prentzas, 2007).

Rules

Rules represent what to do or not to do while certain situations are met. Similarly, the application domain knowledge is represented with set of rules that represent the facts that would be true when some conditions are given true. Rules are captured from domain experts using different knowledge acquisition methods like: Interview, observation and so on. Rules represent **general knowledge** about problem domain in a very **natural** knowledge representation method, keeping knowledge **modularly** and ability to provide **explanations** for the derived conclusions are some of the advantages of rules. Its shortcoming is its difficulty in acquiring complete and perfect knowledge in a complex domain due to the experts may be incapable of expressing their knowledge or unavailability of some experts or willingness of the experts. And also representing the domain with only general knowledge may not be enough.

2.4.2. Rule based reasoning techniques

Rule based reasoning technique is the way that system solves a problem by using knowledge about problem domain that is represented in form of rules. There are two ways of rule based reasoning methods: forward chaining and backward chaining. (Mariana, 2010)

Forward Chaining

Forward chaining offers user to provide the system with information on the problem and keep it in the working memory. The inference engine scans the rules in some predefined sequence looking for one whose premises match the contents in the working memory, It starts with a set of known facts and applies rules to generate new facts whose premises match the known facts, and continues this process until it reaches a predetermined goal, or until no further facts can be derived whose premises match the known facts (Al-Ajlan, 2015; Eshete, 2009).

Backward chaining

An inference engine using backward chaining would search the inference rules until it finds one which has a THEN clause that matches a desired goal. If the IF clause of that inference rule is not known to be true, then it is added to the list of goals. This approach starts with the desired conclusion and works backward to find supporting facts. In another word, the system searches its rules, and if the goal not has been previously proved, it looks for one or more that contains the goal in its THEN part. The system then checks to see if the goal rule's premises are listed in the memory. The system continues in this recursive manner until it finds a premise that is not provided by any rule. When a primitive is found, the system asks the user for information about it. The system then uses this information to help prove both the sub-goals and the original goal (Al-Ajlan, 2015; Tilotma, 2012).

2.4.3. Case based reasoning

Case based reasoning, as its name indicates, uses cases to reason about a given problem. A case usually denotes a problem situation. A previously experienced situation which has been captured and learned in a way that it can be reused in the solving of future problems, which is referred to as a past case , previous case, stored case .Correspondingly a new case or unsolved case is the

description of new problem to be solved . In its problem solving process, it reuses old similar cases to understand the problem, suggest a solution, and/or to keep it from failure (Eshete, 2009; Sonmez, n.d).

Advantages of case based reasoning

Some of the advantages of case based reasoning are discussed as follow: (Prentzas, 2007)

- Their generality: Ability to express specialized knowledge.
- Naturalness of representation: Cases are a simple knowledge representation method and very comprehensible to the user.
- Modularity: Each case is a discrete, independent knowledge unit that can be inserted into or removed from the case base, without any problem.
- Easy knowledge acquisition: Knowledge acquisition in case-based representations is not usually a problem, due to the fact that in most application domains cases are available.
- Self-updatability: Self-updatability facilitates the maintenance of the case base.
- Handling unexpected or missing inputs: A case-based system can handle unexpected cases not recorded in the system or missing input values by assessing their similarity to stored cases and reusing relevant cases.
- Inference efficiency: Adapting preexisting cases to handle new problems is usually more efficient than having to solve a problem from scratch as in rule based.

Disadvantages of case based reasoning

Case based reasoning has some of drawback besides its advantages that discussed above. Some of the limitation issues in case-based reasoning are (Prentzas, 2007):

- Inability to express general knowledge. Cases, by nature, express specialized knowledge. So, they cannot express general knowledge. Rule-based systems have the advantage by the ability to express general knowledge.

- Knowledge acquisition problems. Various knowledge acquisition problems may arise when dealing with domains, where cases are either unavailable or are available in a limited amount.
- Inference efficiency problems. The efficiency of the inference process in CBR is not always the desirable.

Cases

Cases are used to represent domain knowledge of a case based system. A case refers to specific experience or knowledge tied to specific situation that is worth remembering for future use. So that cases in the knowledge base represent collection of specific experienced, captured and learned situations of the application domain.

Each case is constituted with three main parts (Eshete, 2009):

- Situation/Problem description: describes specific circumstances, states of a situation, and state of the environment when this particular case is recorded.
- Solution: provides how the problem described in the problem description was solved or treated in a particular instance.
- Outcome: describes the final result or consequence and feedback gained from following the proposed solution.

2.4.4. Case based life cycle

A case based reasoning technique follows four processes (Aamodt, 1994); retrieve, reuse, revise and retain, to accomplish its reasoning task. A new problem is solved by **retrieving** one or more previously experienced cases, **reusing** the case in one way or another, **revising** the solution based on reusing a previous case, and **retaining** the new experience by incorporating it into the existing knowledge-base (case-base). As below figure 2 shows, an initial description of a problem defines a *new case*. This new case is used to RETRIEVE a case from the collection of *previous cases*. The *retrieved case* is combined with the new case - through REUSE - into a *solved case*, i.e. a proposed solution to the initial problem. Through the REVISE process this solution is

tested for success, e.g. by being applied to the real world environment or evaluated by a teacher, and repaired if failed. During RETAIN, useful experience is retained for future reuse, and the case base is updated by a new *learned case*, or by modification of some existing cases (Aamodt, 1994).

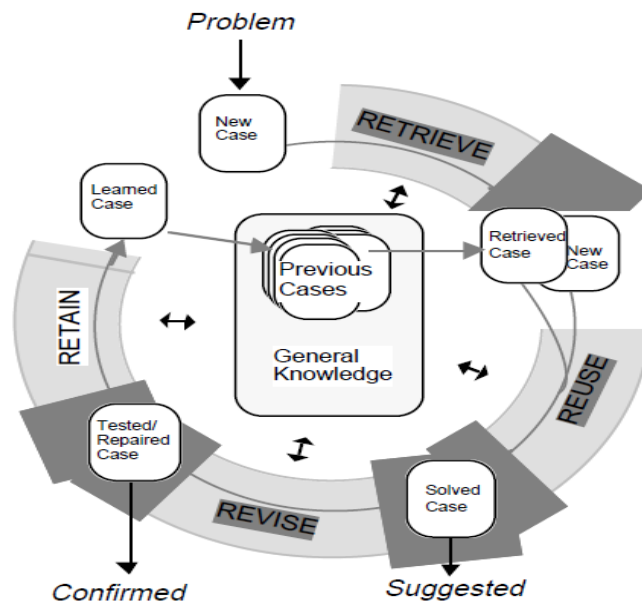


Figure 3 Case based life cycle (Aamodt, 1994).

2.5. Integration of case based and rule based reasoning technique

Case Based Reasoning (CBR) is a methodology for problem solving that focuses on the reutilization of past experience. It is based on solutions, information and knowledge available in similar problems previously solved. A case represents a problem situation. It could be more formally defined as contextualized knowledge that represents past experience, and implies an important teaching to accomplish the objectives of a rational agent.

A rule based reasoning (RBR) system has an inference engine that uses rules to reach conclusions based on premises and a certain context state. Rule-Based Reasoning (RBR) solves problems by performing based on the expert’s knowledge stored in the form of “If–then” rule in the rule base.

In general, however, it is very difficult to make rules without exact exceptions and there are knowledge acquisition bottleneck problem. Efforts were made to solve the short comes of both

rule based and case based reasoning, by integrating CBR (Case-Based Reasoning) Rule-Based Reasoning (RBR. combine rules and cases to produce effective hybrid approaches, surpassing the disadvantages of each component method (Prentzas, 2007; Mariana, 2010).

2.6. Methods of Performance Evaluation

The most important problems in developing knowledge-based systems are the lack of methods to verify and validate the Knowledge Base (El-Korany, 2001). Unlike most conventional software, knowledge based systems are rarely validated and verified against an explicit specification of user requirements. Probably the main reason for this is the lack of a complete and common understanding of the task which is intended to perform among end users, human experts and knowledge based system builders (Meseguer, 1995). Among the components of the knowledge based system, the two major components that compose the intelligent program are a knowledge base and an inference engine. Since the inference engine is algorithmic software i.e., conventional software, software engineering testing techniques can be applied on it. Accordingly, in this system we will use some of the most suitable software engineering testing techniques.

Knowledge based systems evaluation method can be split into Verification, validation, assessment of human factors and assessment of clinical effect. Validation and verification are part of a series of techniques and methodologies applied to the evaluation of a system with the purpose of defining whether its construction is correct (verification); and for defining whether the system corresponds to its initial specifications (validation). These evaluation methods are discussed as follows:

2.6.1. Validation

Validation process is defined as the process of assuring that a system satisfies user requirements. User requirements are clearly application-dependent but they commonly refer to operation conditions, performance level, user interaction, explanation capabilities and acceptance criteria (Meseguer, 1995). In other terms, validation is the process that evaluates the system capacities to solve problems. Validation provides evidence upon which users decide whether or not a knowledge-based system is reliable. Thus, validation ultimately determines the success or failure

of a knowledge based system project (Andradei, 2012; Preece, 2001). Validation allows assuring that a knowledge based system provides solutions that present a confidence level as high as the ones provided by experts.

Validation is then based on tests, desirably in the real environment and under real circumstances. During these tests, the KBS is considered as a “black box” and only the input and the output are really considered important.

2.6.2. Verification

We define *verification* as the process of checking an ES /KBS against the specifications generated by its requirements. The verification process produces accurate responses about the satisfaction of each specification. Often, specifications establish conditions that should (or should not) hold for all the possible ES/KBS executions. To test these specifications, verification has to be exhaustive; it has to analyze all the possible situations where a specification may be violated (Meseguer, 1995).

Verification is an activity in the validation process which aims to verify whether the system attends formal requirements. In other words, verification process evaluates whether the system is appropriately developed. Verification is widely associated to the question: "are we constructing the system correctly?" (Andradei, 2012). Verification allows assuring that a knowledge based system has been correctly conceived and implemented and does not contain technical errors. Verification is intended to examine the interior of the knowledge based system and find any possible errors.

2.7. Knowledge Based System Development Tools

A number of tools that support the development, execution, and maintenance of knowledge-based systems are marketed commercially. In the late 1980s and 1990s, when knowledge based systems was at its peak, approximately 200 knowledge based system tools were commercially available (Kingston, 1989). A knowledge based system tool is a set of software instructions and utilities taken to be a software package designed to assist the development of knowledge-based systems. Knowledge based system can be developed using general purpose programming

languages like java and framework like .NET can also be used in knowledge based system development. These programming languages are general purpose and also being used to develop other application than AI applications.

And also knowledge based system can be developed using knowledge based system shell with the readymade utilities of self-learning, explanation and inference etc. like Java Expert System Shell (JESS), GURU, Vidwan, which are more specific and useful to develop knowledge based system. Knowledge based system can be developed using programming languages like LISP and Prolog. There are various versions of Lisp available namely KLISP and C Language Integrated Production System (CLIPS) (Srinivas, 2010).

Prolog stands for Programming in logic, which was designed in 1972 by Philippe Russel, Alain Colmerauer at the University of Aix-Marseille and Robert Kowalski at the University of Edinburgh. Since 1972, Prolog has been one of the most popular logical programming language. Prolog programs are often described as *declarative*, although they also have part of a procedural element.

There are only two components to any prolog program: facts and rules. Prolog works by specifying facts and rules and uses query and prolog interpreter to retrieve solution for users' queries (Barmer, 2005).

There are different prolog programming languages like: Quintus Prolog, ArityProlog, ALS Prolog, LPA Prolog, and a number of other commercial implementations, as well as freeware Prologs from ESL and SWI. For the purpose of this thesis SWI Prolog programming language is used (Covington, 1995).

2.7.1. SWI-PROLOG

SWI-Prolog is neither a commercial Prolog system nor a purely academic enterprise, but increasingly a community project. The core system has been shaped to its current form while being used as a tool for building research prototypes. Community contributions have added several interfaces and the constraint (CLP) libraries. SWI-Prolog as an integrating tool, supporting a wide range of ideas developed in the Prolog community. SWI- prolog is a versatile implementation of the prolog language. SWI-Prolog is suitable for the overall implementation of

applications. As a consequence, SWI-Prolog has always provided extensive libraries to communicate to other IT infrastructure, such as graphics (XPCE), databases, networking, programming languages and document formats (Wielemaker, 2014; Wielemaker, 2010).

2.8. Applications of Knowledge Based System in Medical Domain

Medical Expert systems are the common type of Artificial Intelligence in medical clinical use. They contain medical knowledge, usually about a very specifically defined task, and are able to reason with data from individual patients to come up with reasoned conclusions. Medical Expert systems hope was that they would become as a perfect doctor, assisting or surpassing clinicians with tasks like diagnosis. Medical artificial intelligence is primarily concerned with the construction of AI programs that perform diagnosis and make therapy recommendations. Some of application area of knowledge based system in medical domain is discussed as below (Aikins, 1983; Coiera, 1993):

1. Diagnostic assistance. When a patient's case is complex, rare or the person making the diagnosis is simply inexperienced, an expert system can help come up with likely diagnoses based on patient data.
2. Laboratory systems. Clinical laboratories have proven to be a good domain for the use of experts systems, both for the interpretation of measured values and automated preparation of reports, as well as in the process of guiding clinicians in the selection of appropriate tests to order.
3. Drug advisory systems- There is clear opportunity to develop systems which assist clinicians with the prescription of medications, checking for drug-drug interactions and side-effects, as well as selecting the most cost-effective treatments.
4. Image recognition and interpretation- Automated systems offer the opportunity to assist with mass screening programs (e.g., mammography) as well as assisting with expensive and complex investigations (e.g. MRI).
5. Signal interpretation- The development of interpretive alarms for real time clinical signals in areas like the intensive care unit will offer some assistance with the task of

clinical vigilance. Automated ECG interpretation and report systems are already a success in the clinical market place, and their improvement will continue to merit some effort.

2.9. Popular Knowledge Based System in Medical Domain

MYCIN: is originally developed by Edward Short life for Stanford Clinical School in the mid-1976. It is one of the first Expert systems developed for clinical guidance. MYCIN is a rule-based Expert system designed to diagnose and recommend treatment for certain blood infections (antimicrobial selection for patients with bacteremia or meningitis). It is later extended to handle other infectious diseases. Clinical knowledge in MYCIN is represented as a set of IF-THEN rules with certainty factors attached to diagnoses. It is a goal-directed system, using a basic backward chaining reasoning strategy (resulting in exhaustive depth-first search of the rules base for relevant rules though with additional heuristic support to control the search for a proposed solution (Saba, 2012).

INTERNIST/CADUCEUS is prepared particularly for internal medicine specialists called Internists. Given some symptoms, deciding on the type of one or more diseases needs the combination of vital clinical signs together with the laboratory result. When we think of many symptoms and many laboratory results of many patients it will be difficult to bear all these in mind during the diagnosis of the disease. Therefore the expert system takes all the input and advices on what to focus in.

PUFF expert system diagnoses the results of pulmonary function tests. PUFF is derivative of **MYCIN** which has been applied successfully to perform task to interpret set of pulmonary function (PF) test results, like volume of the lungs, the ability of the patient to move air into and out of the lungs, and the ability of the lungs to get oxygen into the blood and carbon dioxide out, then it produces a set of interpretation statements and a diagnosis for the patient (Aikins, 1983).

ONCOCIN is also another rule-based system which assists a clinician to plan cancer treatment.

PIP, the Present Illness Program, is a system built by MIT and Tufts-New England Clinical Center in the 1970s that gathered data and generated hypotheses about disease processes in patients with renal disease (Saba, 2012).

PACE stands for the patient care expert system. It was designed in 1977 with the intention of making an intelligent selection from vast and ever changing information related to health. The knowledge base is used by the system software to make easy care plan development. At first the system was designed for educational purpose for the nursing profession. After years PACE has evolved and passed through many development generations. Now PACE has become an advanced clinical management system that can assist the entire health care field to diagnose and care for patient with pulmonary diseases (Tagel, 2013).

2.10. Knowledge based system for maternity care and treatment

Implementation of artificial intelligence in healthcare system is necessary in order to provide fast, effective and efficient services to the clients. Automated healthcare services provide information of the diagnosis and continuous monitoring of patient to acquire immediate response in order to save lives. Expert systems applied in healthcare are important in giving correct information for diagnosis and providing immediate medical services. Below some of knowledge based system in the area of maternity care and treatment are discussed (Mateo, 2008).

Ruszkowski conducted his paper on expert knowledge based consultation for Early Pregnancy Disorders, has used expert knowledge acquisition and rule based methods. The objectives proposed in his work are: suitable consultation procedures concerning EPD (Early Pregnancy Disorder) and comprehensive and reliable medical knowledge acquisition (Ruszkowski, 1988).

Woolery and Grzymala-Busse in 1994 developed Machine Learning for an Expert System to Predict Preterm Birth Risk. This system is designed to predict the risk of delivery before the most recommended week of delivery.

Mothers usually deliver their babies on the 37th week. Deliveries before this time result in premature delivery which affects individuals, families and the health care system.

According to (Woolery, 1994), solutions to this problem may be achieved using machine learning and expert system technology to support health care providers' assessments in this complex domain.

The most successful inductive machine learning technique employed in this project involved the use of a computer program called Learning from Examples using Rough Sets (LERS), which was developed in the Computer Science Department of the University of Kansas by one of the authors. Each of the databases tested surpassed traditional manual accuracy rates in predicting preterm birth. Machine learning programs analyzed preterm delivery or full-term delivery (Woolery, 1994).

2.11. Related works

Seblewongel Esseynew in 2011 conducted her thesis on Prototype knowledge based system for anxiety mental disorder diagnosis. She modeled knowledge acquired using decision tree structure that represents concepts, parameters and procedures involved in anxiety disorders diagnoses. Based on the model, the prototype is developed with SWI Prolog by using 'if – then' rules. The prototype developed uses backward chaining to infer the rules and extract conclusions and recommendations (Seblewongel, 2011).

Tagel Aboneh in 2013 conducted on knowledge based system for pre-medical triage treatment at Adama university asella hospital. He also used decision tree to model knowledge acquired for hospital triage service. The prototype is developed with LPA WIN prolog by using 'if – then' rules. The prototype developed uses backward chaining to infer the rules and provide appropriate recommendations. The objective of the study was to investigate the applicability of rule-based reasoning approach in the development of knowledge based system for hospital triage service so as to improve the quality of decision made by general practitioners, to provide effective and efficient services to the patients and to improve shortage of human expert in specific domain area (Tagel, 2013).

Redeit in 2006 conducted prototype knowledge based system for HIV pretesting counseling. The main objective of the research work was to look into the feasibility of employing the rule based

expert system in the area of pre-test counseling by using the knowledge base system technology (Redeit, 2006).

Anteneh in 2004 conducted research study to investigate the rule based reasoning approach in designing and developing knowledge based system prototype for Anti retroviral therapy in area of HIV treatment as sources of knowledge. The acquired knowledge is represented using hierarchical structure modeling. The research inference engine uses backward reasoning mechanism (Anteneh, 2004).

A number of local researches have been done in the medical domain. All researchers try to investigate apply of knowledge based system in the medical domain area. The researcher employ similar approaches such as rule based techniques to develop the knowledge based system. In addition most of the researches are implemented for specific domain area.

Similarly, the proposed knowledge based system in this study is conducted to explore the applicability of rule based system for maternity care and treatment. The objective of this study is to develop a knowledge base system that assists Health workers in minimizing the number of death of pregnant mothers. For the implementation of this study rule based system technique is used to represent knowledge collected from the experts. Therefore, the proposed knowledge based systems can assist human expert during the diagnosis process and to recommend the appropriate treatments.

CHAPTER THREE

KNOWLEDGE ACQUISITION AND CONCEPTUAL MODELING

3.1. Knowledge acquisition

Knowledge acquisition is the process of extracting, structuring and organizing knowledge from usually knowledge experts. In the process of knowledge acquisition, first, the domain is determined for suitability for expert System. Second, the source of experts must be identified. Third, the specific knowledge acquisition techniques are identified (Jones, 1989).

3.2. Problem Domain Area

Several domain features are listed for consideration in determining whether an Expert system is appropriate for a particular problem domain.

First, people should exist in the domain. In this case, the experts who generate the knowledge for the expert system as well as who make use of the expert system are health professionals in the field of Gynecology. More specifically, nurses, midwives, Doctors who are responsible for Ante Natal and Post Natal care and treatment of maternal mothers. The researcher used health professionals at Gandhi Memorial Hospital in Addis Ababa. Gandhi Memorial hospital is a governmental hospital which specializes in maternity services. Starting from its establishment the hospital has been providing maternity services. Gandhi is chosen using purposive sampling method. There is no specialized maternity governmental hospital other than Gandhi in Ethiopia.

Second, there must be general consensus among experts about the accuracy of solutions in a domain. To assure this consensus, data was collected by an interviewing staffs of Gandhi hospital using purposive sampling.

The interview addressed to those staffs involved in the care, follow up and special treatment of maternal mothers. This includes ANC and PNC nurses, Midwives and Genecology Doctors.

Purposive sampling has been used to select experts for interview using their willingness and experience.

3.3. Knowledge Acquisition Process

According to Mohammad (2010) there are three basic categories of knowledge acquisition methods: Manual, semi-automatic and automatic methods.

In manual methods the knowledge engineer extracts expert knowledge and then codes it in a suitable format. There are many known manual methods like interviewing, process tracking, and protocol analysis, observation, case analysis, and critical incident analysis, discussions with the users, commentaries, and brainstorming.

Semi-automatic method is intended to increase the productivity of cognitivicians and experts. Such methods are divided into two categories: methods that support exports in building a knowledge base, without cognitivicians help and methods that support cognitivicians in executing the specific phases of the knowledge acquisition rapidly and efficiently with less help of the experts.

In automatic methods the roles of both the expert and the knowledge engineer are minimized or even eliminated. Knowledge acquisition is made by the plan architect analyst (Mohammad, 2010).

For the purpose of this research the manual method of knowledge acquisition is used.

3.3.1. Observation

Gandi Hospital uses a Smart Care System in the process of followup and treatment of maternal mothers. A Mother directly go to Triage. The Triage decides where to send the mother and puts an information on a small card. The mother then take the small card and go to the Card room and personal information about the mother is recorded in to the Smart care system. The triage Room continously fetches information from the data stored in the data base by the Smart Care system. The data shows the history of the mother in the previous visits if any. Accordingly, the triage room assigns the department to which the mother should head to, such as In Patient Department, Outpatient department, ANC department, Delivery department, Emergency department,

Gyneacology department receive the mother's information and get the history of the mother from the Smart Care system.

This history is also a history about the previous visits. For instance, if the mother is coming for the 3rd time, the previous 2 visits will be attached with the current vital sign. The major goal of focused antenatal care is to help women maintain normal pregnancies.

3.3.2. Interviewing domain experts

Semi structured interviews were used in the domain area at Gandhi Memorial hospital. The interview was prepared and documented in structured format. The knowledge engineer is then interviewed the experts accordingly by taking notes on the document. Before conducting the interview, observation of the treatment and care process was conducted. The Interview took place at the working place of the hospital in a separate room reserved for the staff as well as when the Ante Natal and Post Natal Care process was going on the working area. During the process of knowledge acquisition health professional's willingness and their busy schedule are some of the challenges faced, but after understanding the purpose of the expert system, some of the health professionals were willing to participate in the interview process, four (10) domain experts were selected using purposive sampling technique. According to the respondents, during the care and follow up of maternal mothers, they use Focused Ante Natal Care. As explained by the experts, ANC is defined as the complex of interventions that a pregnant woman receives from organized health care services. The purpose of ANC is to prevent, identify and treat conditions as well as help a woman approach pregnancy and birth as a positive experience. The care should be appropriate, cost-effective and based on individual needs of the mother. In addition, ANC is an essential link in the house – to – hospital care continuum and helps assure the link to higher levels of care when needed.

The new approach to ANC, called Focuses ANC, emphasizes the quality of care rather than the quantity. For normal pregnancies WHO recommends only four antenatal visits.

➤ Health promotion and disease prevention

Services and counseling provided in this category are:

- Immunization against tetanus.
- Iron and folate supplementation.
- How to recognize danger signs, what to do, and where to get help.
- Voluntary counseling and testing for HIV.
- The benefit of skilled attendance at birth.
- Breastfeeding.
- Establish access to family planning.
- Protection against malaria with insecticide-treated bed nets.
- Good nutrition and the importance of rest.
- Protection against iodine deficiency.
- Risks of using tobacco, alcohol, local stimulants, and traditional remedies.
- Hygiene and infection prevention practices.

➤ Early detection and treatment of complications and existing diseases;

As part of the initial assessment, the provider talks with the woman and examines her for pre-existing health conditions that may affect the outcome of pregnancy, require immediate treatment or require a more intensive level of monitoring and follow-up care over the course of pregnancy.

➤ **Birth preparedness and complication readiness planning.**

Approximately 15% of women will develop a life-threatening complication. So, every woman and her family should have a plan for the following:

- A skilled attendant at birth.

- The place of birth and how to get there including how to access emergency transportation if needed.
- Items needed for the birth.
- Money saved to pay for transportation, the skilled provider and for any needed medications and supplies that may not be provided for free.
- Support during and after the birth (e.g., family, friends).
- Potential blood donors in case of emergency.

During the interview process, the respondents showed a document prepared by Federal Democratic Republic of Ethiopia about management protocol on selected obstetrics topics (Ministry of Health, 2010). Explicit knowledge is also used from the document suggested by the experts, which all cares and treatments to be carried out by health professionals by classifying in to four visits with all details of tasks such as personal history, medical history, obstetric history, and physical examination and laboratory tests.

First Visit

- If the mother's gestational age is not above 16 weeks, she is in the first trimester.
- If the mother is in the first trimester:
 - Take personal history
 - Age, marital status, number of pregnancy, Date of Last Menstrual Period (LMP), regularity of the cycle, Determine expected Date of delivery (EDD), number of abortions, socio economic status such as monthly income, family size, number of rooms, toilet, kitchen.
 - If the cycle is regular, $EDD = LMP + 280$ days
 - If the woman has a history of Genital cutting, if the woman is under age, If the woman has abortion history, special care and treatment is provided.

More number of visits are planned and scheduled in consideration of possible complications.

- Take medical history
 - This is to know If the woman has diabetes mellitus, renal disease, cardiac disease, chronic hypertension, tuberculosis, past history of HIV related illnesses and HAART, varicose veins, deep venous thrombosis, hepatitis, malaria, past or chronic diseases, past or chronic allergy(-ies), chronic diseases in the past Operations other than caesarean section, Blood transfusions. Rhesus (D) antibodies, If the woman has Current use of medicines – specify, any medications
- Take obstetrics history
 - Previous still birth or neonatal loss
 - History of three or more consecutive spontaneous abortion
 - Birth weight of last baby < 2500 gm
 - Birth weight of last baby > 4000 gm
 - Last pregnancy
 - Periods of exclusive breast feeding when for how long
 - Thrombosis, embolus
 - Previous surgery on reproductive tract (Myomectomy, removal of septum, fistula repair, cone biopsy, CS, repaired ruptured uterus, cervical circulage
 - Any unexpected event (pain, vaginal bleeding)
- Perform Physical Examination
 - General appearance, look for signs of physical abuse

- Vital signs: BP, PR, Temperature, RR; HEENT: Check for signs of severe anemia: pale complexion, fingernails, conjunctiva, and buccal mucosa, tip of tongue and shortness of breath. Look for oral hygiene, dental carries
 - Check for signs of jaundice record weight and height to assess the mother's nutritional status
 - Do breast examination
 - Chest: auscultate for chest and heart abnormality
 - Abdomen: measure uterine height (in centimeters). A chart should be used to determine uterine height
 - Gynecological Exam: consider vaginal examination (using a speculum), look for vulval ulcer, vaginal discharge, scratch marks, pelvic mass, cervical lesion and estimate uterine size in first trimester, genital malformation, severe FGM.
 - Assess for symptoms of AIDS and HIV as per WHO Clinical Staging System for HIV status for HIV positive women.
- Laboratory tests
- Urine analysis preferably multiple dipstick test for bacteriuria and test for protein uriato all women.
 - Blood: syphilis (rapid test - RPR if available or VDRL) result while waiting in the clinic.
 - Blood-group typing (ABO and rhesus)
 - Hemoglobin (Hb) or hematocrit.
 - Stool exam if the woman can afford or if it is provided for free or when presumptive treatment using mebendazole is not recommended

- Perform HIV test if the woman does not say “NO”. Encourage testing of partner
 - Perform CD4 count for all HIV positive pregnant women, If CD4 determination is unavailable, HIV positive pregnant women should be staged clinically and using total lymphocyte count for antiretroviral treatment, ART, eligibility.
 - Additional investigations that can be considered when available and affordable include: urine culture and sensitivity, ultrasound, Pap smear.
- Implement the following interventions:
- Iron and folate supplements to all women: one tablet of 60-mg elemental iron and 400 micrograms folate per day.
 - To enhance the absorption of iron, instruct mothers to take iron when eating meat or vitamin-rich foods (fruits and vegetables).
 - Avoid tea, coffee, and milk at the same time when taking iron; it interferes with the body’s absorption of iron. Iron can also be taken between meals.
 - If rapid test for syphilis is positive: treat, provide counseling on safer sex, and arrange for her partner’s treatment and counseling.
 - Tetanus toxoid: give first injection.
 - In malaria endemic areas provide ITN.

The details of four visits that extracted from (Ministry of Health, 2010) can be found in appendix.

3.4. Common symptoms and remedies

There are common symptom observed in a pregnant woman and accordingly remedies proposed by physician. Table 1 summarizes the common symptom and remedies.

Table 1 Common symptoms and remedies

Complaint	What to Tell the Client	Management Provided
Constipation	<ul style="list-style-type: none"> • Increase your water intake (8 glasses); • Eat high-fiber foods, and take daily exercise. • Use mild laxatives as a last resort 	<ul style="list-style-type: none"> • Counsel the client on diet • Suggest mild laxatives only if the other measures have failed.
Headache	<ul style="list-style-type: none"> • Take mild pain relievers; <i>e.g.</i>, paracetamol. Avoid aspirin. • Inform provider if pain becomes severe. She should attend the health facility 	<ul style="list-style-type: none"> • Determine that the headache is not a <i>Danger Sign</i> • Offer paracetamol (Panadol) 300 mg every 3-4 hours. • For severe headache or migraine, offer codeine or other related narcotic might be used. • Remember headache can be associated with hypertension.
Backache	<ul style="list-style-type: none"> • Avoid excessive bending, lifting, or walking without a rest period. • Rock pelvic periodically during the day for relief. • Wear supportive, low-heeled shoes. • If severe, wear a maternity girdle for additional support. • Heat or ice to back for relief, whichever is more comforting. 	<ul style="list-style-type: none"> • Counsel regarding comfort measures. • Remember: the Symptoms of UTI and onset of labor include backache.
Nausea and Vomiting	<ul style="list-style-type: none"> • Eat small, meals frequently. Keep crackers at bedside and eat before getting out of bed. Eat fruit or drink fruit juice before going to sleep. • Avoid oily, spicy foods. • Get out of bed slowly. • Symptoms should not extend beyond the first three months; if severe and persistent; see your health care provider. 	<ul style="list-style-type: none"> • Counsel about comfort measures. • Provide Vitamin B6, 50 mg, twice daily. • If symptoms are severe, refer for possible hospitalization and intravenous fluids. • Medications for management may include: <ul style="list-style-type: none"> - promethazine (Phenergan) - Diphenhydramine (Benadryl) –Other antihistamines • Birth defects have not been

		associated with the use of these drugs.
Varicosities	<ul style="list-style-type: none"> • Elevate legs periodically during the day. • Wear support hose (elevate legs before putting on hose for maximum support). 	<ul style="list-style-type: none"> • Prescribe support hose, as necessary. • Refer if varicosities are severe and painful.
Vaginal Discharge	<ul style="list-style-type: none"> • Cleanse genitalia daily. Wear cotton underwear. • Use light sanitary pads if discharge is heavy. • Avoid vaginal douching. • If discharge develops with itching, irritation or unpleasant odor, see the provider as soon as possible for treatment. 	<ul style="list-style-type: none"> • If not infection, counsel for genital hygiene. • With symptoms of infection, treat according to guidelines or refer for treatment.
Leg cramps	<ul style="list-style-type: none"> • During cramping, straighten leg slowly with the heel pointing and the toes upward or push the heel of the foot against the footboard of the bed or floor, if standing. • Exercise daily to enhance circulation. • Elevate legs periodically throughout the day. • Take calcium tablets daily. Eat calcium rich foods such as dairy and dark green leafy vegetables. 	<ul style="list-style-type: none"> • Prescribe calcium carbonate or calcium lactate tablets.

3.5. Conceptual Modeling

Conceptual modeling is a technique that helps to clarify the structure of a knowledge-intensive business task. Knowledge model specifies the knowledge and reasoning requirements of the prospective system; the communication model specifies the needs and desires with respect to the interfaces with other agents: i.e., a user interface and/or interfaces with other software systems. Together, the knowledge model and the communication model form the input for system design and implementation. Input for the conceptual-modeling process is a task identified during business modeling (Schreiber et al., 1999).

3.5.1. Decision tree structure for maternal follow up and treatment

Maternity health is achieved through maternal follow up and treatment. Maternal follow up is performed in Ethiopia at least four times before birth depending on the recommended follow up by World Health Organization. In each of the four visits, checkup as well as treatment and advice is performed. This decision tree model of the knowledge base which helps to make decision during the follow up and treatment is structured in all the four visits. Each visit contains personal, medical and obstetric history; physical examination and laboratory tests; and medical interventions.

Visits are separated in trimesters. Trimesters are three subdivisions in the total time which takes a woman to give birth, usually 37 to 42 weeks. First trimester is from start to 16 weeks. Second trimester is from 17 to 28 weeks. The third trimester is from 29 to 37 weeks. As a woman appear before a health professional, prior making any checkup or treatment, the week of the pregnancy should be known. There are some women who come to the visit in the second or third trimester without attending the first or the second trimester. In such cases, knowing the right time of pregnancy is important to provide the appropriate health service. In order to provide all the knowledge, we start by deciding the season of the pregnancy. Then according to personal, medical, obstetric history and physical examination and laboratory test, decisions specific to the situation are generated by the knowledge base. Decision trees contained in this model have detailed child and grandchild branches to represent tasks to be performed. Each decision tree starts with a each of four visits and delivery mode. Each attribute is important to present the picture of the problems.

Complaints of clients decision tree

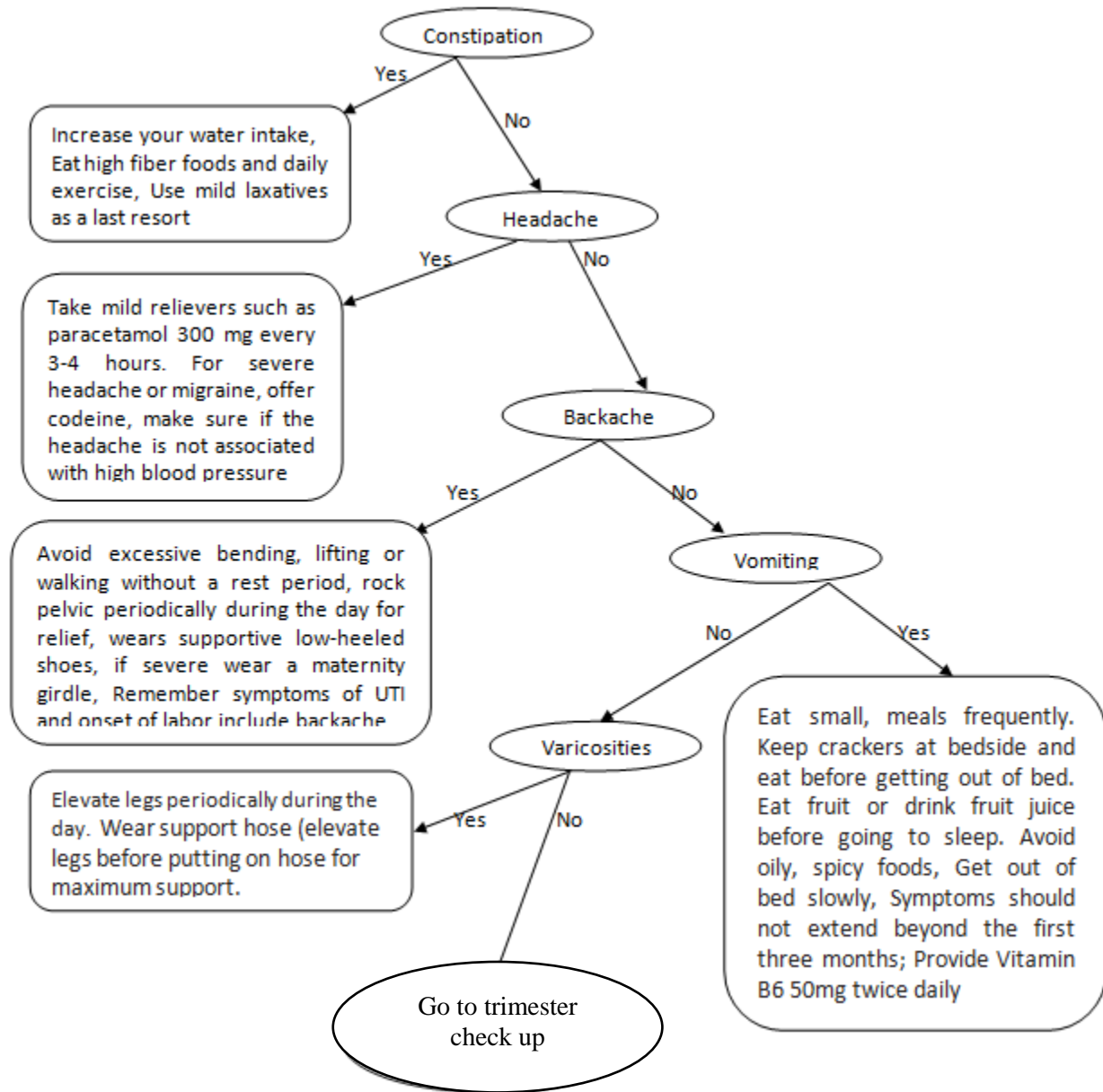


Figure 3 Decision tree for complaint management

According to the document provided by the Ministry of Health, the complaints of the woman should be addressed before conducting checkup of the trimester (Ministry of Health, 2010). For instance, it is not possible to start a new issue ignoring the woman with constipation.

If the woman is feeling constipation, it will be relieved by increasing water intake, eating high fiber foods and working daily exercise. If the constipation is not changing after taking all these measures, medicines such as mild laxatives should be used as a last resort.

Sometimes pregnant women feel very high headache. This should be treated by giving them mild relievers such as, paracetamol 300 mg every 3-4 hours. If the headache grows to be severe and changed to migraine, codeine can also be given. Here, it is very important to make sure whether the headache is not associated with High blood pressure.

Back aches happen in most pregnant women because of the load they carry. We need no medicine to resolve such kind of issues. It is enough to give some suggestions such as, avoiding excessive bending, lifting or walking without rest. Related to the load they carry, varicosities may also happen. To avoid these problems advice should be given to the woman to elevate legs periodically during the day.

Vomiting is the well-known issue in pregnant women. Taking anti vomit medicines is not advisable in this case is happening in the first three months of pregnancy. This complaint can be addressed by changing the eating and moving styles. These includes, eating small meal frequently than eating much once and avoiding spicy foods and getting in and out of bed slowly.

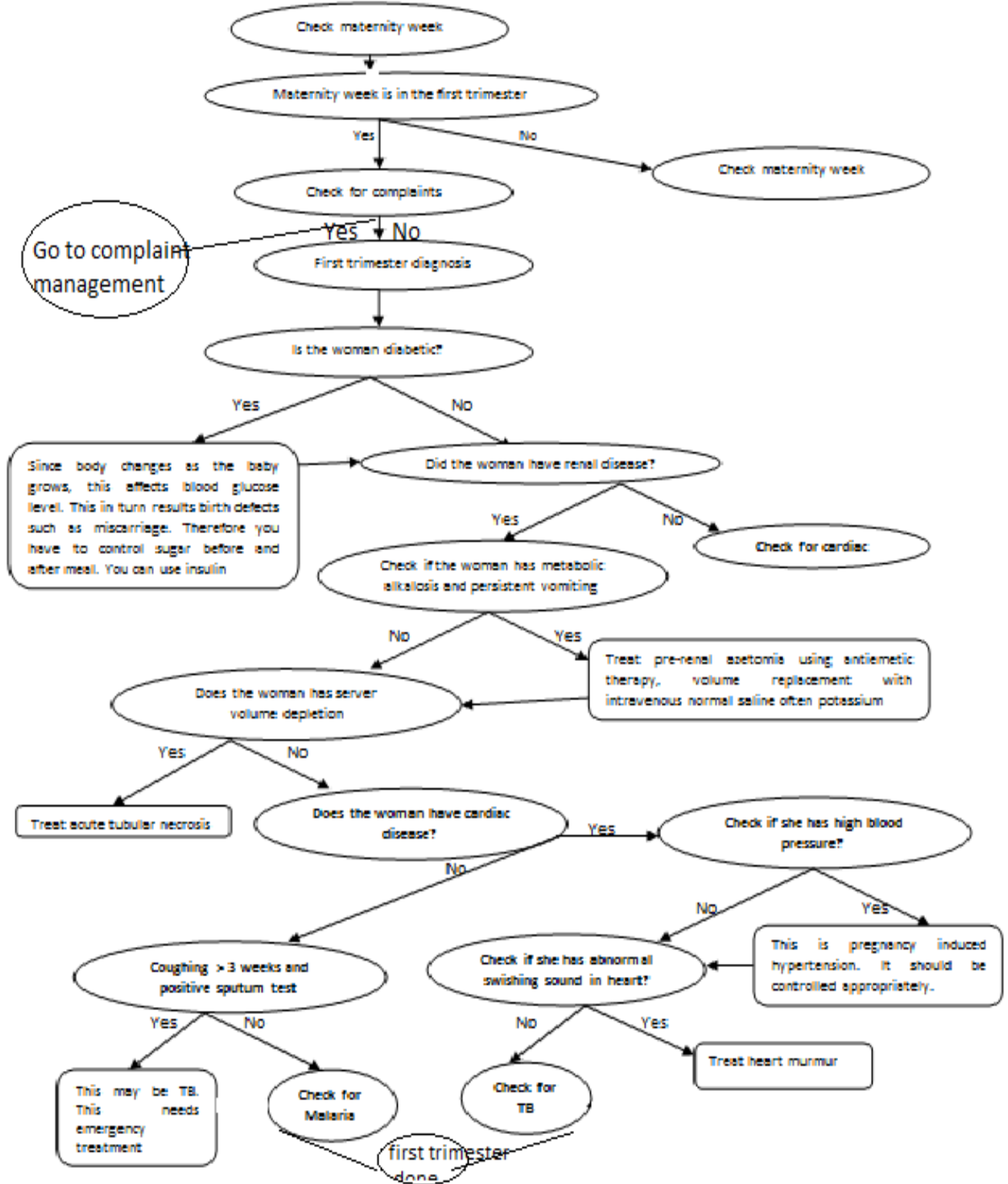


Figure 4 Decision tree for first trimester

Figure 4 indicate that, the first trimester period ranges from first week to 16 weeks of pregnancy. Prior check-up of a trimester, complaints of the mother should be addressed. If there are no complaints, the first trimester checkup starts. In the first trimester, basic health issues for the mother are checked. These include diabetic mellitus, renal disease, cardiac problems, tuberculosis and malaria.

Second trimester

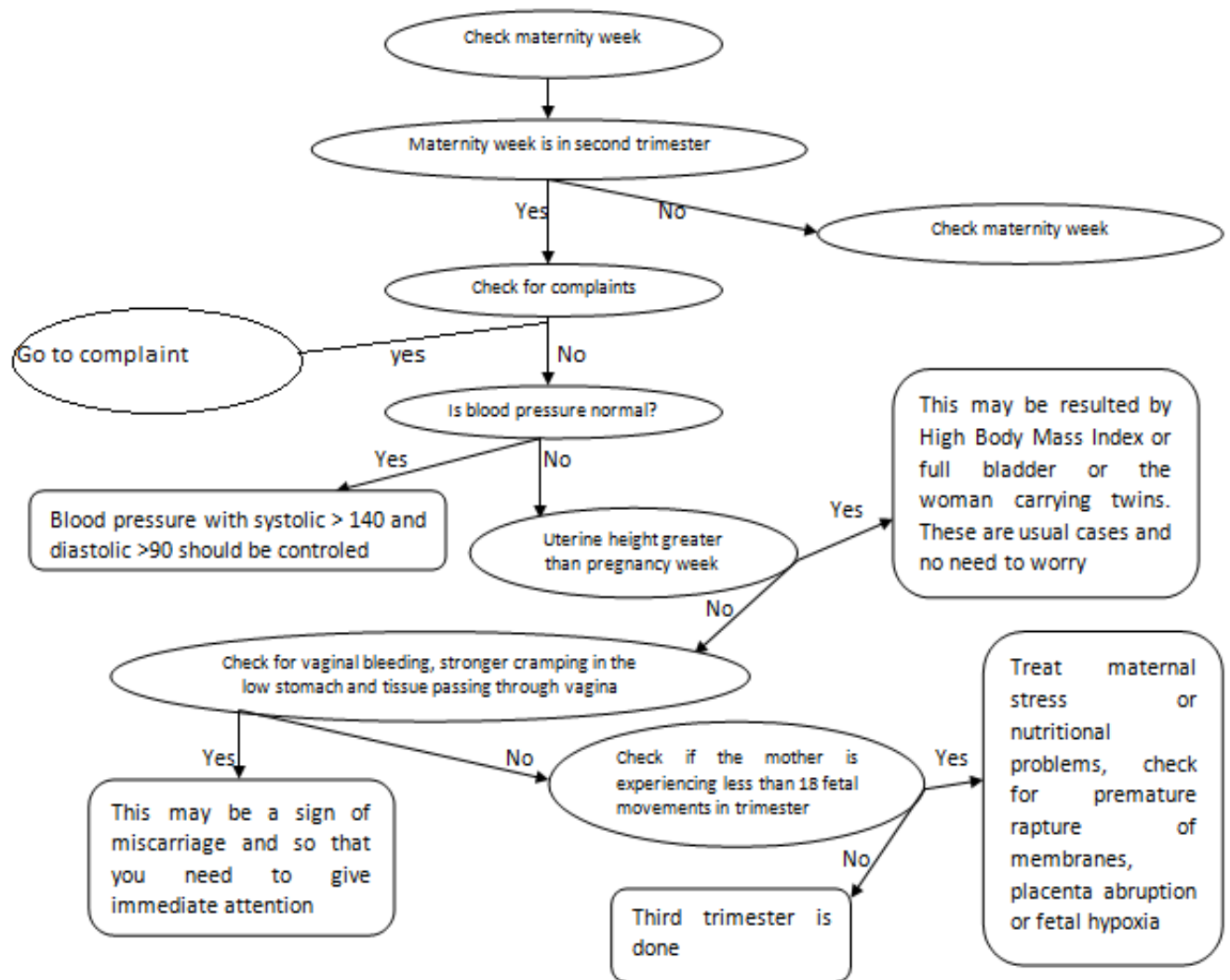


Figure 5 Decision tree for second trimester

Figure 5 indicate that, after checking maternity week, maternity week between 28 and 37 is categorized under third trimester. If the woman is in the third trimester, before starting the check up for the third trimester, she should be listened if she has any complaints on her health so that it will be managed accordingly. If she has no complaints detail checkup for the third trimester will start. In the third trimester, the first thing to be checked is blood pressure. If not well handled early, problems associated with high blood pressure result in dangerous obstetric complications. Blood pressure with systolic greater than 140 and diastolic greater than 90 is abnormal. Abnormal blood pressure should be controlled. The next concern is about uterine height. Uterine height measured by fingers should be equal with the expected week to the baby. If the height is more than expected this may be result of high blood pressure, full bladder or the woman carrying twins. If this is the case, it should be considered normal. Otherwise great attention should be given.

Other big concerns of the third trimester are: the occurrence of vaginal bleeding, stronger cramping in the lower stomach and tissue passing through vagina. This may be a sign of miscarriage and so that you need to give immediate attention. Lastly, check if the mother is experiencing less than 18 fetal movements in the trimester. If this case, treat maternal stress or nutritional problems. Check for premature membranes, placenta abruption or fetal hypoxia.

Delivery type decision tree

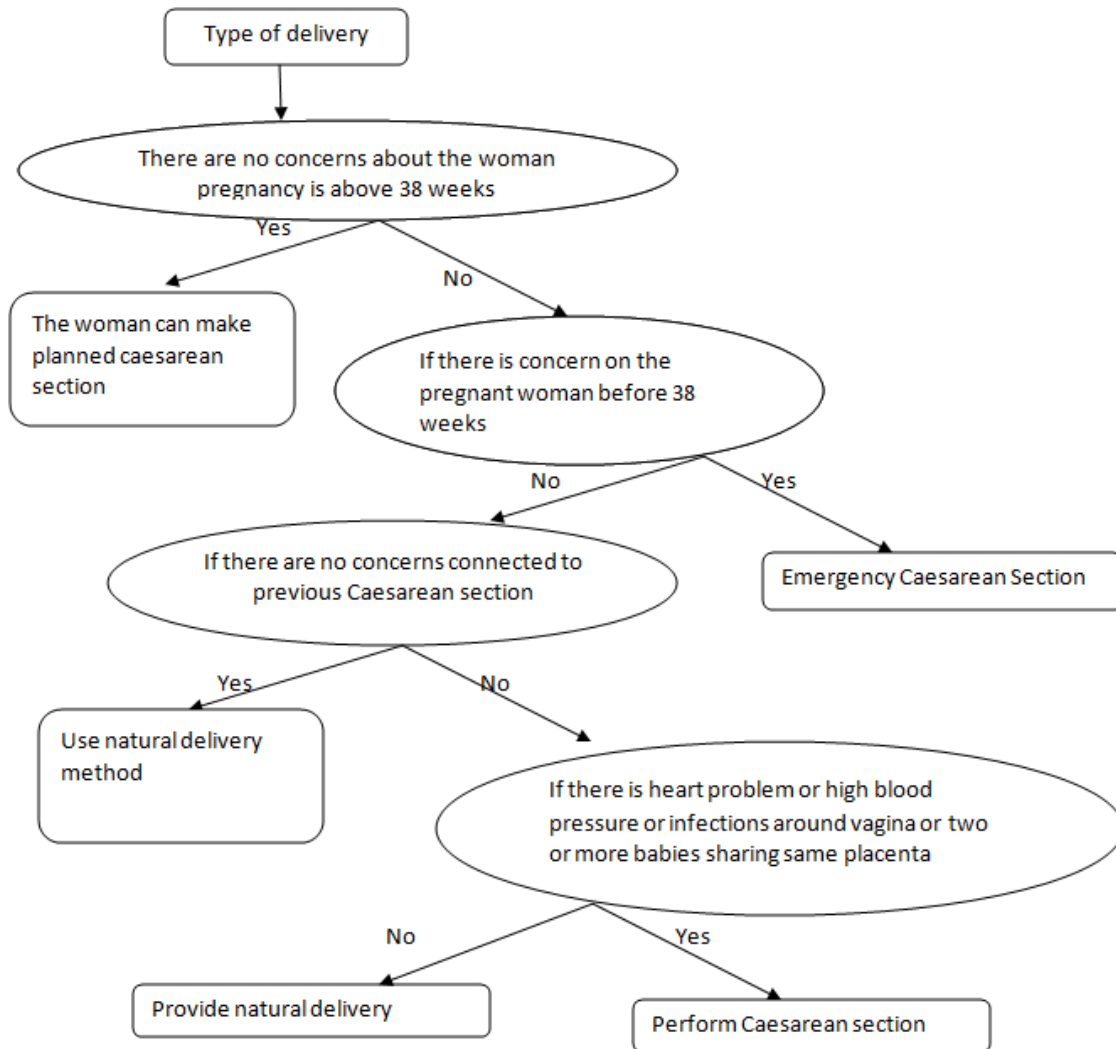


Figure 6 Type of delivery decision tree

As shown in the figure 6, type of delivery is decided based on numerous criteria. The first thing to make note of is the status of the woman in the periods before delivery. A woman has 37 to 42 weeks before delivery. If the status of the woman is in a complicated obstetric case before delivery, an emergency caesarean section should be conducted. If the woman has passed over 42 weeks, a planned caesarean section should be conducted. The other condition to be considered here is about the relation between previous caesarean section. If the woman has already had a caesarean section in previous births and this is very near to the previous pregnancy, natural birth is not recommended. Other things which need attention during the choice of the type of delivery include, if there are heart problems, high blood pressure, infections around vagina, two or more

babies sharing the same placenta, the type of delivery should be Caesarean section. If all of the above conditions do not persist natural delivery could be the choice.

3.6. Knowledge representation

Knowledge representation and reasoning is the field of artificial intelligence dedicated to representing information about the world in a form that a computer system can utilize to solve complex tasks such as diagnosing a medical condition or having a dialog in a natural language.

Knowledge representation incorporates findings from psychology about how humans solve problems and represent knowledge in order to design formalisms that will make complex systems easier to design and build. Knowledge representation and reasoning also incorporates findings from logic to automate various kinds of *reasoning*, such as the application of rules or the relations of sets and subsets.

The followings are if-then representation of the knowledge base system for maternity care and treatment.

If woman complain constipation

Then advise her to increase water intake,

And/or Eat high fiber foods and daily exercise,

And/or use mild laxatives as a last resort

If the woman's age < 20,

And/or the woman has history of genital cutting,

And/or the woman has history of genital cutting,

And/or the woman has history of abortion before pregnancy,

Then provide special care, plan more visits and check for other conditions

If the woman has cardiac disease,

And/or the woman has high blood pressure,

And/or the woman has protein in urine

And/or the woman has swelling due to fluid retention

Then Treat pregnancy induced hypertension (PIH)

If woman has systolic >140,

And/or diastolic >90,

Then control hypertension

If woman uterine height is greater than pregnancy week

Then woman has high BMI,

And/or woman has full bladder,

And/or woman is carrying twins

CHAPTER FOUR

KNOWLEDGE BASED SYSTEM IMPLEMENTATION

The prototype, knowledge based system in this research is developed using prolog. The implementation of the knowledge base system in prolog is both compact and readable due to the following features of Prolog:

- Each rule is represented as a single Prolog term (a relatively complex structure).
- The functions of the rule structure are defined as operators to allow the easy-to-read syntax of the rule.
- Prolog's built-in backtracking search makes rule selection easy.
- Prolog's built-in pattern matching (unification) makes comparison with working storage easy.
- Since each rule is a single term, unification causes variables to be automatically bound between LHS conditions and RHS actions.
- The Prolog database provides an easy representation of working storage.

Each rule is a single Prolog term, composed primarily of two lists: the right hand side (RHS), and the left hand side (LHS). These are stored using Prolog's normal data structures, with **rule** being the predicate and the various arguments being lists.

The proposed prototype implementation depends on the decision tree structure, which is easy to code using prolog. Decision trees uses rule-based models to describe the knowledge acquired from domain expert. The ‘if-then’ rules of knowledge based system are generated based on the decision tree structure.

The knowledge based system incorporates user interface, developer interface, inference engine, knowledge base, rules in the knowledge base, and explanation facility components.

4.1. User interface

The user interface of the prototype is used as the means of communication between a user and the prototype knowledge based system.

The Dialogue which is held with the health professionals are on natural language. After the dialogue, the consultation or suggestion, is provided in the same manner. All the procedure of the system is built according to the decision tree model.

```
*****  
*                                                                 *  
*                WEL COME                                       *  
* This program provides advise on maternity care and treatment *  
*                                                                 *  
* *****  
Enter the Week of the woman: █
```

Figure 7 Welcome screen of the system

The prototype starts the user interface by a welcome screen as shown in the above figure 7. The welcome screen appears after the user has typed a ‘start’ predicate. Since the purpose of this knowledge base is to follow up and treat maternity cases, the four major maternal visit periods should be identified by the week the woman is in.

Figure 8 below shows that, If the woman is below week 17, this period is first trimester and all maternity cares that should be provided in this trimester are supplied by the knowledge base. Second trimester diagnosis runs, if the woman is above week 17 and below week 28.

Third trimester diagnosis runs if the woman is between week 28 and week 37. The postpartum will be triggered if the woman is above 37 weeks.

```

Enter the Week of the woman: 12.
The woman is in the first_trimester care
Check for the:
    - Age is less than 20
    - have Abortion history and
    - have Genital history
If the above conditions persist, you have to provide special care
Special care includes:
    - Planning more visits
*****
Now, check for other conditions.....

Did the woman has Diabets ? (y or n)
|: █

```

Figure 8 Dialogue screen of the system

The other interface is about each specific follow up case to be followed. According to first trimester, the first case to be checked is Diabets. As shown in the figure 8, the user should enter 'Y' or 'y' for Yes and 'N' or 'n' for no plus dot ('.'). The knowledge base system responds accordingly, until all cases are assured. This system runs all the cases exactly according to the decision tree.

```

*****
Now, check for other conditions.....

Did the woman has Diabets ? (y or n)
|: n.
Check for renal disease
Did the woman has renal disiease? (y or n)
|: y.
If the woman has renal disease further diagnosis should take place
Did the woman has metablolic alkalosis and
Persistent vomiting ?
|: n.
Check some more things...
Does the woman has severe volume depletion ?
Does the woman has hypermesis gravidarum ?
Does the woman has hemmorage ?
|: y.
Treat acute tabular necrosis.
Treatment includes:
    - Fluid resuscitation
    - pressers for hypotension
    - Antibiotics or
    - dialysis
. .

```

Figure 9 More Dialogue screen of the system

For all the cases and in all trimisters, the same approach is followed. All portions of the system in the user interface, are coded using Prolog as a programming language.

4.2. Developers interface

The knowledge based system is developed in Notepad and consulted in SWI Prolog interface. The program is designed as in the following manner.

The fact named as interpret contains the ASCII codes for 'Y', 'y', 'n', and 'N'. Interpret changes the ASCII code in to Yes and No value.

The Yes or No value is argument for all predicates in the prolog program. Start is the first predicate which starts the whole program just after the user typed the predicate start followed by a dot ('.').

Follow up cases are organized as predicates and each predicate contains ask, response, reply and knowledge predicates. This development environment helps any knowledge engineer to expand the system in the future whenever needed.

4.3. Inference engine

Inference engine is the code at the core of the system, which derives recommendations from the knowledge base and problem-specific data in working storage. Prolog has a built-in backward chaining inference engine that can be used to partially implement some expert systems. Prolog rules are used for the knowledge representation, and the Prolog inference engine is used to derive conclusions.

The Prolog inference engine does simple backward chaining. Each rule has a goal and a number of sub-goals. The Prolog inference engine either proves or disproves each goal. There is no uncertainty associated with the results.

This rule structure and inference strategy is adequate for many expert system applications. Only the dialog with the user needs to be improved to create a simple expert system.

Manage (complaint):-

Constipation == (yes);

Headache == (yes);

Backache == (yes);

Vomiting == (yes);

Varicosities == (yes).

From the above rule, if the woman has a complaint of constipation, headache, backache, vomiting, and/or varicosities, then a match is found and inference engine draw conclusion. The conclusion is managing woman's complain by advising what she has to do. But, if the woman doesn't have any constipation the inference engine continuous checking until it get match. If all possible complaints are checked and there are no complaint found, inference engine goes to first trimester and check each rule sequentially.

4.4. The knowledge base

Knowledge based of the prototype contains all knowledge acquired from domain experts during knowledge acquisition process. It contains the basic care and follow up definitions, which will be used by the instances of cases. The knowledge base is divided into six parts, designed to make it easy for the expert to examine and maintain it. These are: Main rules for the parameters; Rules for derived information; Questions for the user; Rules for complex validation; Rules for complex default calculations; Static information. The acquired domain knowledge is represented using rule based representation method as a set of "if – then" rules. Facts base is also constructed based on the knowledge gained from domain experts. The facts in the facts base are used to match against the 'if' (condition) part of rules. if the given facts satisfy all the conditions which proved to be true, then the inference engine draw a conclusion.

Rules in the knowledge base

```
diagnosis(first_trimester):-
  write('Check for the: '),nl,
  write('      - Age is less than 20 '),nl,
  write('      - have Abortion history and'),nl,
  write('      - have Genital history '),nl,
  write('If the above conditions persist, you have to provide special care'),nl,
  write('Special care includes:'),nl,
  write('      - Planning more visits '),nl,
  write('*****'),nl,
  write('Now, check for other conditions..... '),nl,nl,
  ask_diabets,
  response(Reply),
  diabets(Reply).
```

Figure 10 First trimester diagnosis interface

The first category among the four major categories is patient is in the first trimester. What is performed for patient in the first trimester? The first thing is to make sure if special care should be provided.

Provide special care if:

- Age of the woman is less than 20
- The woman ever has abortion history
- The woman ever has genital cutting history

Whether special care is provided or not, the next care is immediately provided. In this case, as shown in the above figure, diabetes is the first condition to be checked in the first visit. The woman is asked for diabetes, the response is held in the response predicate. The other predicate is the diabetes.

```

Did the woman has renal disease? (y or n)
|: y.
If the woman has renal disease further diagnosis should take place
Did the woman has metabolic alkalosis and
Persistent vomiting ?
|: n.
Check some more things...
Does the woman has severe volume depletion ?
Does the woman has hypermesis gravidarum ?
Does the woman has hemmorage ?
|: y.
Treat acute tabular necrosis.
Treatment includes:
- Fluid resuscitation
- pressers for hypotension
- Antibiotics or
- dialysis
. .

```

Figure 11 Treatment dialogue interface

To maintain continuity according to the response from the diabetes which is ‘Yes’ or ‘No’, the No response for the diabetes is redirected to asking the user for renal case. The same procedure applies here. The ask predicate asks the woman if the woman ever had renal disease. The reply predicate receives the answer from the woman and the response will be input to the argument of the renal predicate.

4.5. KBS Testing

The most important problems in developing knowledge-based systems are the lack of methods to verify and validate the Knowledge Base (El-Korany, 2001). Unlike most conventional software, knowledge based systems (KBS) are rarely validated and verified against an explicit specification of user requirements. Probably the main reason for this is the lack of a complete and common understanding of the task which a KBS is intended to perform among end users, human experts and KBS builders (Meseguer, 1995).

Among the components of the knowledge based system, the two major components that compose the intelligent program are a knowledge base (KB) and an inference engine (IE). Since the inference engine is algorithmic software i.e., conventional software, software engineering testing techniques can be applied on it. Accordingly, in this system we will use some of the most suitable software engineering testing techniques.

4.5.1. Verification and Validation

Verification and validation can be viewed as a set of techniques and an associated process in which the techniques are applied as part of the whole development process. KBSs developers are realizing that in order to compete in the commercial computing community a KBSs must display quality not only in its performance but also in its structure and developing process. Ensuring the quality of KBSs involves two types of activity:

- a) Activities intended to assure that the KBS is structurally correct (verification activities) and
- b) Activities intended to demonstrate KBS ability to reach correct conclusions (validation activities).

The earliest validation technique in AI was Alan Turing's proposal on how to decide if a program could be considered "intelligent", commonly known as the Turing test. This is a blind test where the evaluator communicates through a teletype with a person and a program.

If the evaluator is unable to differentiate between the person and the program, the program is considered to be intelligent.

In addition to testing, KBS developers realized that rule bases could be analyzed for anomalies which are indicative of errors in the construction of the KBS and which can lead to faulty behavior at run time. Commonly considered anomalies include inconsistency, redundancy, circularity, unreachable goals, and unreadable rules. Tools to detect such anomalies were called verifiers due to the logical nature of the tests.

Nowadays, validations and verifications are performed in combination as testing methods in order to obtain maximum evidence as to the correctness of KBS.

Verification

The Verification process of the KB ensures that the system is free of induced errors by the developer as well as ensuring matching between the specification of the system and what the system actually does.

Human Analysis

Human analysis techniques usually rely on individuals to use their expertise to find errors in the knowledge based system (KBS). These types of analyses are error prone, as they do not rely on the semantics of the knowledge, and in general are not automated. Review, walkthrough and inspection are the most common techniques that could be used to verify the knowledge.

The system is tested by the same expert during knowledge acquisition which selected purposively and ICT staffs of Gandhi Hospital to test coding standards of the system developed by prolog. The standards are derived from Artificial intelligence center in University of Georgia written by Michael A. Covington in December, 2002 (Michael, 2002).

These standards are very important in assuring the expandability of the system in the future by ICT staffs of the hospital. There are 5 ICT staffs in the hospital, all participated in code standard testing. The questioners are developed from standard to test artificial intelligence and answered “Yes” and “No”.

Table 2 Human analysis test1

No.	Questions	Yes	No
1.	Every predicate start with an introductory Comment in the standard format.	✓	
2.	The arguments in the introductory comment are descriptive	✓	
3.	All names are pronounceable.	✓	
4.	No two different names that are likely to be pronounced alike are used.	✓	
5.	Predicate names are constructed with lower case	✓	
6.	Predicate words are separated with underscores.	✓	
7.	Numbers are not expressed with words	✓	
8.	Arguments are placed in inputs, intermediate results, and final results order.		✓
9.	Arguments are mapped in to ordinary English	✓	
10.	First lines of each clause are indented.	✓	
11.	Each sub goal is put on a separate line except closely related pairs such as write and nl.	✓	
12.	Separate clauses are used instead of semicolon (;)	✓	
13.	Non portable codes are isolated		✓
14.	Magic numbers are isolated	✓	
15.	Error messages are informative		✓
Total		12 (80%)	3 (20%)

As shown in table 2 above, 80% of the code is up to the standard. Which means future developments in to the system can be easily applied by internal ICT staffs of the hospital. They can read and understand the system as their own system and correct or maintain any future faults.

Table 3 Human analysis test 2

No.	Questions	Poor (1)	Fair (2)	Good (3)	Very good (4)	Excellent (5)	Average	Average percent
1.	Is the rules in the prototype are easy to Understand?			2	4	4	4.2	84%
2.	Is user interface attractive?		2	6	2		3	60%
3.	Is the system efficient in time?		2	2	2	4	3.8	76%
4.	How much accurate the system in providing care and follow up?				4	6	4.6	92%
5.	Does the system incorporate sufficient In the follow up and care?				6	4	4.4	88%
6.	Does the system provide appropriate Care and follow up for the women?			2	2	6	4	80%
7.	Does the system have contribution in the Domain area?				2	8	4.8	96%
Total average							4.11	82.28%

All ten (10) experts working in the area of antenatal care and postnatal care are questioned the above questions and their responses are analyzed.as follow.

As table 3 describes, 14.28% say the rules in the prototype are good to understand at the same time, 38% say the prototype is very good and the rest 37% rated excellent. For ‘interface attractiveness ’13.3% of the respondents say the user interface fair. 60% of user rated as good and the rest of the respondent 26.6% very good. This indicates that we need a more attractive interface as which we have indicated in the future works of this system it is more applicable if it

is developed using Visual Prolog. For the system 'efficiency and timely' 10.5% of the respondents say that the system is fair and time efficient, 15.7 of respondent rate good, and also 21% of the respondent rated very good. And the rest 52.6% of the respondents said the system excellent. For question 'accuracy', 34.7% of the respondent evaluated the system as very good and the rest of the respondent 65.2% rate excellent. For the question 'system is sufficient', 54.5% responded very good and the rest 44.4% rated excellent about incorporation of sufficient knowledge in the system. For question 'appropriateness' of the system, of the respondent 15% rated good and 20% rated very good. The rest of the respondents 75% rated excellent. For the question 'contribution of the system in the domain area, 16.6% of the respondent rated very good and the rest respondent 83.3% rated excellent.

To summarize table 3 average performance of system evaluated by ten evaluators is 4.11% of the scale of 5. The result indicated that 82.28% of the user is satisfied by performance of knowledge based system.

Validation

Validation ensures that the output of the system is correct and the developed system is what the user want and need. Validation ensures that the knowledge it contains correctly represents and simulates the domain knowledge. In this process, we determine the appropriate method to automatically generate test cases for each KB component.

Test Case Generation

The method we use to test each component of the knowledge base in this case is automatic test. This test serves certain aspect in knowledge validation. Automatic test ensures the quality of the solution (the solutions provided by the system conform to the solution expected by the expert),

In Automatic test, test cases are automatically generated in the form of input concept-attributes pair and their suggested values. These suggested inputs are applied to the component to be tested and the output is ranked. The tester provides both the knowledge engineer and the domain expert by a list of test cases. This list of test cases serves two functions:

- First the knowledge engineer compares it with the requirement specification to check consistency between them.
- Second, the domain expert finds out whether they meet the required knowledge or not.

Cases are generated as in the following table. Cases are selected from each of the four visits. The cases are selected randomly. The results or summary from the real cases are compared with the results or summary with the system.

Table 4: The accuracy of the knowledge based system in completely and correctly followed and treated women by the knowledge based system

Table 4 Test cases

No.	Selected follow up and treatment	selected cases as input	completely and correctly followed and treated	incompletely and incorrectly followed and treated cases	The accuracy of the test cases in percent (%)
1.	First Visit follow up and treatment	5	4	1	80%
2.	Second Visit follow up and treatment	5	4	1	80%
3.	Third Visit follow up and treatment	5	5	0	100%
4.	Fourth Visit follow up and treatment	5	5	0	100%
	Total	20	18	2	90%

As shown in table 4 above, twenty test cases are selected purposively to validate the accuracy of the system and five cases are assigned for each maternal visit. The women were selected from

already passed cases documented in the hospital. The summaries attached in each woman are compared with what the knowledge based system summarizes.

At the beginning of each visit, the procedure dictates the health professionals to ask for any complaint the mother has ever faced during the trimester before going deep in the trimester issue (Ministry of Health, 2010). The common complaints to be checked are: constipation, headache, backache, vomiting, and varicosities. The first test checks whether the system follows this procedure or not. In this case five mothers are selected and the system after given the week of maternity starts by asking for common complaints for the right trimester.

On the other hand, the health professionals use additional related complaints based on the response for the given complaints for the five women selected. Here, constipation was related to gastric which the system was unable to related to. Rather the system asks some fixed five complaints only. Accordingly, the system provided correct complaints handling for four out of the five women selected for this test.

Among the women who carried out the second visit, four of the five women were provided visit correctly. One of the checkups held are making sure whether there is no connection with the previous visit to second visit. The problem with the one woman was she was gastric and maternal stress is connected with gastric. When maternal stress becomes tense to the woman the gastric will get complicated. Since the system did not keep track of history of the woman, it is unable to handle such kind of situations correctly.

4.6. Discussion

The knowledge based system is evaluated in three different testing techniques. In the code standard testing, which was tested by all ICT staff members, the result was 80%. User acceptance testing which was tested by ten Ante Natal and Post Natal Care experts the result was 82.28%. In the performance testing of the system, the result was 90%. The average result of all the test options is 84%. This result indicates that the knowledge based system for maternity care and follow up is assessed to be good. The knowledge based system is incorrectly and incompletely treated 10%, because the developed knowledge based system cannot keep track of previous history of woman so, it can relate and treat or advice correctly.

Accordingly, it is possible to say the knowledge based system can fully assist human experts to provide better health care service, specifically for maternity care and treatment. In another word the proposed knowledge based system makes the right decision and appropriately advice during maternity care and treatment.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Some of the contributing factors for pregnancy related problems are: the need for high level health professional expertise, the need for advanced health care systems, the need for advanced health infrastructure, and inconsistency of decisions among health professionals.

In order to address these challenges and minimize maternal mortality of women who didn't deserve to die while giving life, knowledge based system plays very essential role. A knowledge base developed from knowledge of highly qualified and more experienced maternal health experts will be used by any health professional with more or less qualification and experience

Generally, we can conclude this study as follows:

- The knowledge based system have been proved that it fully supports the follow up, care and treatment of maternal women in all the visits
- The system categorizes women in the right trimester and visit and provides advice accordingly using rule based reasoning developed through decision tree model.
- Knowledge is represented in the form of if then rules generated from the decision tree.
- The proposed knowledge based system uses Validation and Verification model of testing using test cases and user acceptance respectively to test the system against the purpose and objectives. The result of system performance indicated that users are satisfied with proposed system and the system correctly advice and treat maternity in each for visits with small difference.
- The knowledge base contains every task to be included during the visit based on the official document provided by Ministry of Health Ethiopia.
- The developed knowledge based system has no database to catch up the history, it will be better to include database for better performance of the system.

6.2. Future works

- This knowledge based system is developed using SWI-prolog. In relation to Graphic user interface, it will be more applicable if it is developed using Visual Prolog.
- The system will perform better if integrated with advanced data base system to store the result of summary in to permanent storage.
- It will be better to include means of incorporating self-learning of knowledge based system.

6.3. Recommendation

The study achieves its main objectives by proving the applicability of the rule based system for maternity care and treatment. Based on the findings of the study the following recommendations are suggested for the applicability of knowledge based system in the domain area. Other researchers can investigate more the implementation of knowledge based system in related health domain.

- To make use of this system by hospital or health station can use it by integrating in to an existing system or as a standalone desktop application
- Integration needs to access this system from Server side scripts and sharing it among all the users. Integration is more possible because of the nature of prolog in that it doesn't consume much storage space and processor.
- To use it as a standalone application the system should be prepared in a package to be run by installers.
- For better result, developing case based system or integrating both rule-based and case based is recommended.

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Appendix I

Interview Questions

For the purpose of data collection interview questions are prepared. Before conducting interview knowledge engineer introduced the objective of the study and appreciates their willingness and also requests their active participation in the study. The following are questions that are asked during the interview with domain experts.

1. How many visits are necessary for a woman during pregnancy?
2. Is there any categorization of pregnancy months?
3. What are the different problems that happen during pregnancy?
4. What are the basic steps to follow during maternity care?
5. How does detail diagnosis of maternity treatments goes?
6. What are the important points that you take in to account when making diagnosis in each of visits?
7. How does diagnosis for each trimester proceed?
8. What are the major issues covered by the diagnosis processes of each visits?
9. How do you identify the major symptoms of each trimester?
10. What are the major symptoms and complications in each trimester that may happen?
11. What are the critical symptoms that need immediate action during pregnancy?
12. After completing the diagnosis, what are the major decisions or action that you may make?
13. What are the major difficulties and challenges in maternity care and treatments?

Appendix II

```
diagnosis(first_trimester):- complaints,

    write('Check for the: '),nl,

    write('    - Age is less than 20 '),nl,

    write('    - have Abortion history and'),nl,

    write('    - have Genital history '),nl,

    write('If the above conditions persist, you have to provide special care'),nl,

    write('Special care includes:'),nl,

    write('    - Planning more visits '),nl,

    write('Now, check for other conditions.....    '),nl,nl,

    ask_diabets,

    response(Reply),

    diabets(Reply).
```

```
response(Reply):-get(Code),
```

```
    get0(_),
```

```
    interpret(Code,Reply).
```

% Interpret predicate interpretes the answers provided by the user
from

```
ask_diabets:- write('Did the woman has Diabets ? (y or n)'),nl
```

diabets(yes):- write('Establish a consistent Check and control of sugar level'),nl,
write('Advice the woman to have regular exercise and balanced diet'),nl,
diabets(no).

diabets(no):- write('Check for renal disease'),nl,

ask_renal,

response(Reply),

renal(Reply).

ask_renal:-write('Did the woman has renal disiease? (y or n)'),nl.

Appendix III

Questionnaire to test the performance of the knowledge based system for maternity care and treatment.

1. Is the rules in the prototype are easy to understand?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

2. Is user interface of KBSMCT attractive?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

3. Is the system efficient in time?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

4. How much accurate the system in providing care and follow up?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

5. Does the system provide appropriate care and follow up for the women?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

6. Does the system have contribution in the domain area?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

6. Does the system have contribution in the domain area?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

Appendix IV

Questionnaire to test the performance of the knowledge based system for maternity care and treatment by ICT staff.

1. Every predicate is started with an introductory Comment in the standard format.

A. Yes B. No

2. The arguments in the introductory comment are descriptive

A. Yes B. No

3. All names are pronounceable.

A. Yes B. No

4. No two different names that are likely to be pronounced alike are used.

A. Yes B. No

5. Predicate names are constructed with lower case.

A. Yes B. No

6. Predicate words are separated with underscores.

A. Yes B. No

7. Numbers are not expressed with words.

A. Yes B. No

8. Arguments are placed in inputs, intermediate results, and final results order.

A. Yes B. No

9. Arguments are mapped in to ordinary English.

A. Yes B. No

10. First lines of each clause are indented.

A. Yes B. No

11. Each sub goal is put on a separate line except closely related pairs such as write and nl.

A. Yes B. No

12. Separate clauses are used instead of semicolon (;).

A. Yes B. No

13. Non portable codes are isolated.

A. Yes B. No

14. Magic numbers are isolated.

A. Yes B. No

15. Error messages are informative.

A. Yes B. No

Appendix V

Knowledge Representation

If woman complain constipation

Then advise her to increase water intake,

And/or Eat high fiber foods and daily exercise,

And/or use mild laxatives as a last resort

If woman complain headache

Then advise her to take mild relievers such as paracetamol 300 mg every 3-4,

And/or offer codeine,

And/or make sure if the headache is not associated with high blood pressure

If woman complain backache

Then advise her to avoid excessive bending,

And/or lifting or walking without a rest period,

And/or rock pelvic periodically during the day for relief,

And/or wears supportive low-heeled shoes,

And/or if severe wear a maternity girdle,

And/or check if it is or not sign of labor

If woman complain vomiting

Then advise her to eat small portion of meals frequently

And/or Keep crackers at bedside and eat before getting out of bed

And/or eat fruit or drink fruit juice before going to sleep

And/or avoid oily and spicy foods,

And/or Get out of bed slowly,

And/or Provide Vitamin B6 50mg twice daily

If woman complain varicosities

Then elevate legs periodically during the day

And/or wear support hose (elevate legs before putting on hose for maximum support).

If the woman's age < 20,

And/or the woman has history of genital cutting,

And/or the woman has history of genital cutting,

And/or the woman has history of abortion before pregnancy,

Then provide special care, plan more visits and check for other conditions

If the woman has diabetes mellitus,

Then check and control sugar level,

And work regular exercise,

And use balanced diet

If the woman has renal disease,

And/or the woman has metabolic alkalosis,

And /or the woman has persistent vomiting,

Then Treat prerenal azotemia using antiemetic therapy,

And/or volume replacement with intravenous normal saline often potassium

If the woman has hemorrhage,

Then treat acute tubular necrosis using fluid resuscitation

And/or pressers for hypotension,

And/or antibiotics,

And/or dialysis

If the woman has cardiac disease,

And/or the woman has high blood pressure,

And/or the woman has protein in urine

And/or the woman has swelling due to fluid retention

Then Treat pregnancy induced hypertension (PIH)

If the woman has cardiac disease,

And/or the woman has abdominal swishing sound,

And/or the woman has increase in blood volume,

Then treat Heart Murmur

If the woman has coughing for more than 3 weeks

And the woman has positive sputum test

Then treat tuberculosis.

If the woman has history of varicose veins

And/or the woman has stretch marks

Then treat varicose veins by elevating legs periodically during the day and wearing support hose

If the woman has flu like symptoms,

And/or the woman has tiredness,

And/or the woman has aches and pains,

And/or the woman has stomach pain,

And/or the woman has nausea,

And/or the woman has vomiting,

And/or the woman has diarrhea,

And/or the woman has loss of appetite,

Then treat Hepatitis B or refer to specialist

If the woman has fever,

And/or has headache,

And/or has vomiting,

And/or has cough,

And/or has general malaise,

And/or has respiratory distress,

Then treat Malaria

If woman has systolic >140,

And/or diastolic >90,

Then control hypertension

If woman uterine height is greater than pregnancy week

Then woman has high BMI,

And/or woman has full bladder,

And/or woman is carrying twins

If woman has vaginal bleeding,

And/or strong cramping pain felt low in the stomach,

And/or tissue passing through vagina,

Then provide immediate attention this may be a sign of miscarriage

If woman has less than 18 fetal movements in the whole trimester,

Then treat maternal stress or nutritional problems,

And/or premature rupture of membranes

And/or placenta abruption,

And/or fetal hypoxia

Appendix VI

Knowledge extracted from minister of health manual.

Second Visit

- If the woman is between 17 - 28 Weeks she is in second trimester.
- If the mother is in the second trimester, perform pertinent examination and laboratory investigation (BP, uterine height, multiple dipstick test for bacteruria), proteinuria for those who are nulliparous and for those who have history of hypertension or preeclampsia/eclampsia, determine hemoglobin if clinically indicated
- Assess fetal well being
- Design individualized plan
- Advice on existing social support
- Decide on the need for referral based on updated risk assessment
- Review Personal and medical history and note any changes since first visit.\
- Ask the woman how she is feeling
- Review relevant issues of obstetric history as recorded at first visit.
- Ask about
 - Vaginal bleeding and vaginal discharge
 - Dysuria, frequency, urgency during micturition
 - Severe/persistent headache or blurred vision
 - Difficulty breathing
 - Fever

- Severe abdominal pain
- Fetal movement; note time of first recognition in medical record.
- Signs and symptoms of severe anemia,
- Ask about other specific symptoms or events such as opportunistic infections in HIV positive women.
- Note abnormal changes in body features or physical capacity (e.g. peripheral swelling, shortness of breath), observed by the woman herself, by her partner, or other family members.
- Check on habits: alcohol, smoking other.
- Physical examination
 - Note general appearance, look for signs of physical abuse
 - Check vital signs: BP, PR
 - Uterine height in centimeters
 - Auscultate for fetal heart beat
 - Other alarming signs of disease: shortness of breath, coughing, generalized edema, other..
- Laboratory tests
 - Urine: repeat multiple dipstick test to detect urinary-tract infection; if positive treat and appoint for repeat urine analysis and management after two weeks.
 - Repeat test for proteinuria if the woman is nulliparous or if she has a history of hypertension, pre-eclampsia or eclampsia in a previous pregnancy.

- Blood: repeat Hb only if Hb at first visit was below 7 gm/dl or signs of severe anemia are detected on examination.

The third visit

- If the woman is around 28 – 37 weeks, she is in the third trimester.
- If the woman is in the third trimester:
 - Address complaints and concerns
 - Perform pertinent examination and laboratory investigation (BP, uterine height, multiple dipstick test for bacteruria, determine hemoglobin for all, proteinuria for nulliparous women and those with a history of hypertension, pre-eclampsia or eclampsia
 - Assess for multiple pregnancy, assess fetal well being
 - Review individualized birth plan and complication readiness including advice on skilled attendance at birth, special care and treatment for HIV positive women
 - Advice on family planning, breastfeeding
 - Decide on the need for referral based on updated risk assessment
 - Note any changes or events since second visit.
 - Review relevant issues of medical history as recorded at first and second visits.
 - Note inter current diseases, injuries or other conditions and additional histories for HIV positive women since first visit and the second visit.
 - Note intake of medicines other than iron and folate
 - Iron intake: compliance.

- Note other medical consultations and hospitalization
- Obstetric history
- Review relevant issues of obstetric history as recorded at first visit and as checked at second.
- Record symptoms and events since second visit: Ask about
 - Vaginal bleeding and vaginal discharge
 - Dysuria, frequency, urgency during micturition
 - Severe/persistent headache or blurred vision
 - Difficulty breathing
 - Fever
 - Severe abdominal pain
 - Fetal movement; note time of first recognition in medical record.
 - Other specific symptoms or events such as opportunistic infections in HIV positive women.
 - Changes in body features or physical capacity, observed by the woman herself, her partner or other family members.
 - Check on habits: alcohol, smoking and other.
- Physical examination
 - Measure blood pressure and pulse rate
 - Uterine height: record on graph
 - Palpate abdomen for detection of multiple fetuses.

- Fetal heart sounds: Use pinard stethoscope, hand-held Doppler required only if no fetal movements are seen, the woman feels less fetal movement or if she requests it and it is available.
- Generalized edema.
- Other alarming signs of disease: shortness of breath, cough, etc.
- If bleeding or spotting: Do not do vaginal examination (see section on APH).
- Breast examination.
- Laboratory Test
 - Urine: repeat urine analysis for infection preferably multiple dipstick test to detect urinary-tract infection; if still positive after being treated at a previous visit, refer to special unit in the clinic or a hospital. Repeat proteinuria test only if the woman is nulliparous or she has a history of hypertension, pre-eclampsia or eclampsia in a previous pregnancy.
 - Blood: Hb to all women.
- Implement the following interventions:
 - Ensure compliance of iron and folate and refill as needed
 - Tetanus toxoid injection as needed.
 - Anti – D is given if the woman’s blood group is Rhesus negative and Coomb’s test is negative.

Fourth Visit

- Note any changes or events since the third visit.
- Review relevant issues of medical history as recorded at the three previous visits.

- Note inter current diseases, injuries or other conditions since third visit.
- Note intake of medicines other than iron and folate.
- Iron intake: compliance.
- Note other medical consultations, hospitalization or sick-leave in present pregnancy, since the third visit.
- Final review of obstetric history relevant to any previous delivery complications.\
 - Record symptoms and events since third visit: Ask about
 - Vaginal bleeding and vaginal discharge
 - Dysuria, frequency, urgency during micturition
 - Severe/persistent headache or blurred vision
 - Difficulty breathing
 - Fever
 - Severe abdominal pain
 - Fetal movement; note time of first recognition in medical record.
 - Changes in body features or physical capacity, observed by the woman herself or by her partner, or other family members.
- Physical examination
 - Measure blood pressure and pulse rate.
 - Uterine height: record on graph.
 - Check for multiple fetuses.

- Fetal lie, presentation (head, breech, transverse).
- Fetal heart sound(s): use pinard stethoscope.
- Generalized edema.

- Laboratory
 - Urine: Urine analysis for infection (preferably multiple dipstick test to detect urinary-tract infection); if still positive after being treated at a previous visit, refer to hospital. Repeat
 - Proteinuria test only if the woman is nulliparous or she has a history of
 - Hypertension, pre-eclampsia or eclampsia in a previous pregnancy.

- Continue Iron

DECLARATION

This thesis is my original work and has not been submitted as a partial requirement for a degree of master in any other university.

BISILE KEBEDE

October 2016

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